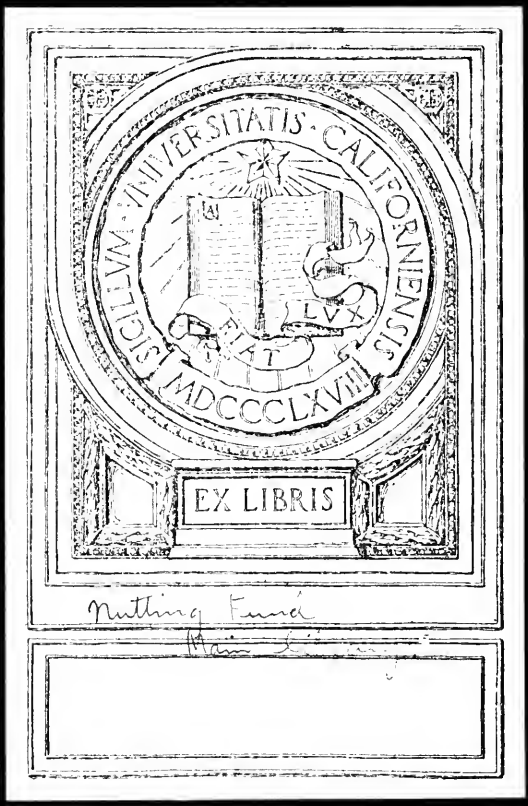

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 660

Contribution from the Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C. September 12, 1918

HIGHWAY COST KEEPING

By

JAMES J. TOBIN and A. R. LOSH
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Reviewed by

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CONTENTS

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GOVERNMENT PRINTING OFFICE
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CONTENTS.

PART I.

COST KEEPING IN GENERAL.

THE FUNDAMENTALS OF COST KEEPING.

Definition.—Cost keeping is a system for recording the cost of each unit of product or division of work in order to facilitate comparison of such costs with cost of other similar units or divisions under like conditions. Cost keeping analyzes each unit of product or work to determine the reasonableness or unreasonableness of the cost, and also to secure an intelligent basis for predicting the cost of producing similar units in future.

Lack of cost records.—The Office of Public Roads and Rural Engineering, in an extensive investigation of highway management, both by the State highway departments and by a large number of individual counties and townships, brought out, among other conditions, the very general absence of cost keeping. Few examples of practical and efficient cost keeping were found in operation, and

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these were confined largely to the State highway departments. Only in rare instances were cost-keeping systems found in counties or townships. This condition is due largely to the notable scarcity of information available on the subject of highway cost keeping, as practically all textbooks on cost keeping have been prepared from the viewpoint of factory management and are not readily adaptable to highway work. Furthermore, the usefulness of highway cost data has not yet been generally appreciated by public officials.

Purpose of the bulletin.—The purpose of this publication is to present, first, in an elementary way the principles which govern cost keeping; second, a practicable application of those principles to highway work.

Development of cost systems.—Cost keeping was developed in the manufacturing industries. To Charles Babbage has been conceded the honor of having first called the attention of the manufacturing world to its desirability, in 1832, in his publication entitled "The Economy of Manufacture." Half a century elapsed, however, before factory managers, forced by relentless competition to eliminate waste and incompetency from their factories, began to introduce systems of cost keeping.

Since 1900 the use of cost keeping in manufacturing industries has developed steadily. During this period of development principles regarded as basic have been established. While cost keeping for highway work is of comparatively recent origin, it is based upon factory cost keeping, and the same principles govern.

COST ELEMENTS.

The term "cost," as generally interpreted and as used in this bulletin, is the summation of expenditures expressed in terms of money involved to acquire or produce a utility or to perform a service.

The cost of every unit of product, whether it be a square yard of road surface maintained, or a cubic yard of concrete which is a part of a bridge or culvert, is composed of four basic elements of expense, namely:

(1) The cost of labor.
(2) The cost of materials.
(3) The cost of service of plant and equipment.
(4) The cost of general expense or overhead.

LABOR.

The costs of labor are divided into two classes; first, direct labor cost; and, second, indirect labor cost. All labor chargeable against the product which can be designated as directly expended on it is called direct labor. All labor chargeable against production and not directly expended on the product is called indirect labor.

For example, the cost of men using picks and shovels on excavation who are directly expending their efforts on that piece of work is a direct labor charge. A superintendent in charge of a road job is not directly expending labor on excavation, but is engaged in directing the prosecution of all kinds of work and his expense is an indirect labor charge, chargeable pro rata against the production of all the work units he may be supervising. Other examples of indirect labor are the services of watchmen, timekeepers, and water boys.

MATERIALS.

Materials also are divided into two similar classes—direct and indirect. All materials entering the product as an integral part of its composition are called direct materials. All materials chargeable against the production but which do not enter directly into the product as an integral part of it are called indirect or expense materials or sometimes supplies. The cement, stone, and sand that are mixed together to form the concrete of which a concrete road is constructed are all direct materials, but the oil used for lubricating and the gasoline for operating the mixer in which these materials are prepared for use are indirect materials or supplies. It is easy to charge direct material cost, but often it is very difficult to charge to each product its correct share of indirect material cost.

Small, or hand, tools not used as a part of some plant unit and which have such a short period of usefulness that they are seldom used on more than one job, usually are considered supplies and therefore are part of the indirect materials charged to the work.

PLANT AND EQUIPMENT.

"Plant" includes such physical property used on the work as land, structures, machinery, live stock, and tools of a more permanent character than those referred to as supplies. "Equipment" is a less inclusive term and is interpreted generally to mean the smaller and especially the movable plant units. The cost of the service of "plant" can be charged most readily in the form of a daily rental against the work upon which it is used. This rental should be charged whether the equipment be owned by the operating organization or leased from other owners. It consists of "operating charges," which are—

(*a*) The expense of operation,
(*b*) The average cost of repairs,
(*c*) Charges for the time spent in idleness,

and "fixed charges," which are—

(*d*) Charges for depreciation,
(*e*) Interest,
(*f*) Taxes,
(*g*) Insurance.

The expense of operation.—This includes the wages of operators and helpers and the cost of supplies during the periods of operation. Usually these are charged directly against the work done and not included in the plant rental. It is only necessary that they be charged in one place or the other, and it is important to specify what is included in rental when leasing equipment.

The average cost of repairs.—There is a difference of opinion among cost accountants as to how repairs and renewals to plant should be charged. One view is that renewals may be of such a nature that the useful life of the machine has been increased and therefore the expense of such renewals should be looked upon as an offset to depreciation. Another view is that there is no difference between repairs and renewals, except in degree, and that they all should be considered in the same light; i. e., independent of depreciation charges. It appears that the latter consideration permits simpler accounting and does not rely so much upon individual judgment as to whether the expenditure is for repairs or for renewals.

After a machine has been rebuilt or repaired extensively with the intention of increasing its serviceable life, it should be considered as a piece of new equipment valued at its depreciated value, plus the cost of renewals. This necessitates the computing of a new rate of depreciation on the basis of the new value and assumed new useful life.

The approximate average cost of repairs, including extraordinary repairs, often can be arrived at by casting up old accounts and finding what a similar piece of machinery used on similar work has cost for repairs over a term of years.

Charges for time spent in idleness.—To arrive at a fair and equitable daily charge for rental some allowance must be made for time spent in idleness, because on these days the fixed charges still are continuing and certain supplies are necessary even though the machine be not in operation. The usual way of arriving at the charge for lost time through idleness is to bring together all of the charges for a year and divide them by the number of days the machine actually was in use. By dividing the sum total of expense by the number of days the machine was available for use even though no work existed on which it could be used, the result would be a daily rental with no allowance for lost time. The difference between these two rentals will show what a considerable factor in the fixed charges this item of lost time may become. In all contracts or agreements on rental of equipment care should be taken to specify whether the rental is "per day" or "per day of service."

Charges for depreciation.—Equipment is consumed in production just as truly as material. This loss is called natural depreciation. Depreciation may be either natural or functional. "All equipment

progresses steadily toward the scrap pile, starting the date it is purchased, and while its progress may be delayed it can not be prevented by repairs." [1] It is as much an expense on a steam roller as the cost of fuel burned in the fire box. In the case of fuel the expense is immediate; in the case of depreciation the expense is extended over a period of time. Functional depreciation is loss due to the obsolescence or inadequacy of equipment.

There is no doubt in the minds of cost accountants that depreciation of plant and equipment should be included as a charge against operation, but there is considerable difference of opinion as to how depreciation should be computed.

Three factors determine in all cases what the depreciation should be: First, the original cost; second, the length of useful life; and third, the scrap value of the machine when it no longer can be used for the purpose for which it was purchased, or the salvage value, if it is to be considered as a "second-hand" piece of equipment. Knowing these factors, the problem resolves itself into how to divide the difference between the original cost and the scrap or salvage value (called total depreciation or wearing value) over the length of the useful life of the machine. A number of formulas have been devised for computing decrease in value or depreciation. Fish, in his textbook on "Engineering Economics," explains five such formulas. Three of the more commonly used are the straight line, the declining balance, and the sinking fund.

The first is recommended as the simplest and perhaps best method for road work. By this method the total depreciation is divided by the number of years of useful life and the quotient charged off as a yearly depreciation. This is called the straight-line method, and its greatest advantage is its extreme simplicity.

The second method, a modification of the straight-line method, is called the declining balance method. It is based on the theory that during the earlier years of the life of any machine the repairs are smallest, and therefore to arrive at a constant charge for repairs and depreciation, the depreciation must be heaviest in the earlier years of the life of the machine and lightest in the last. The plan, therefore, is to charge off a fixed percentage annually from the net value of the machine. This gives a diminishing annual charge for depreciation. In the comparative table (p. 6) this annual rate is about 30 per cent. This is determined by the formula $r = 1 - \sqrt[n]{\frac{v_2}{v_1}}$ in which r is the percentage of diminishing value, n the life of the equipment in years, v_1 the original value, and v_2 the scrap value.

[1] Modern Accounting, by H. R. Hatfield.

The third method is called the sinking-fund method. It is based on the assumption that the depreciation on a structure at any time is equal to the accumulations of a sinking fund established for renewal at the end of its useful life. The depreciated value plus this sinking fund (actual or imaginary) at any period equals the original cost.

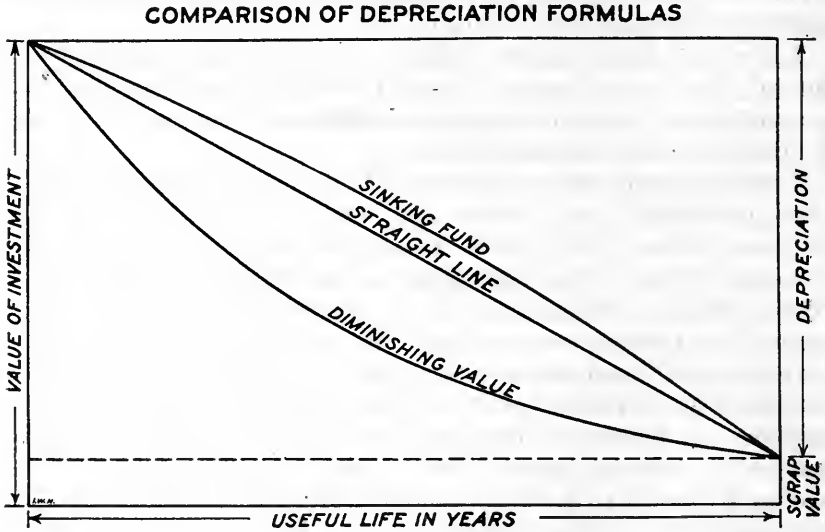

FIG. 1.

It should be observed that none of these formulas takes into consideration interest on investment, output, cost of operation, or maintenance charges. Figure 1 gives a graphic comparison of the above formulas.

The following table is a comparison of the annual depreciation on a $600 machine that has an assumed useful life of five years. It also is assumed that at the end of this period it will have a scrap value of $100. The annual depreciation is computed by the three formulas described:

Comparison of three methods of computing depreciation.

Years.	Straight-line method.	Diminishing-value method.	Sinking-fund method, 6 per cent interest.
First	$100	$180.72	$88.70
Second	100	126.28	94.02
Third	100	88.25	99.66
Fourth	100	61.67	105.64
Fifth	100	43.08	119.98
Total	500	500.00	500.00

The theory of natural depreciation, epitomized, is that all equipment, even if kept in the best of repair, in time will reach a state where repairs no longer are sufficient to keep it in economical working condition and the entire machine must be renewed. The fund created by the depreciation charges is intended to supply the money to purchase a new machine to take the place of the one expended, or to retire the original investment in case the machine no longer is needed.

Any of the depreciation formulas is satisfactory in determining rental charges, provided the assumed life of the machine be approximately correct. As the assumption of the useful life of the machine may be the source of considerable error, there seems to be little argument for the finer calculations as to methods of distributing the depreciation.

It will be found convenient in computing depreciation to group elements of the plant having approximately the same serviceable life. This will have the advantages of requiring fewer accounts and tending to equalize high and low assumed machine life.

Repairs and renewals are charges due to breakage or the wearing out of expendable parts of equipment. It is obviously incorrect to charge to repairs or renewals any improvements or betterments added to any piece of equipment. When such improvements have been made the cost should be added to the present value of the machine and a new depreciation computed upon this new value. An example of such a case would be the addition of a conveyor to an old stone crusher for the purpose of doing away with shovelers. The The improvement is not a repair of any broken parts or a renewal of any part worn out by the continual use of the machine; it is a new feature which adds to the value of the crusher. A rebuilt second-hand machine may be considered in the same light.

Interest, taxes, and insurance.—Interest should be charged on the investment at the rate paid or the prevailing rate, where there is no indebtedness.

Taxes, as paid, should be charged in the rental rate.

Insurance should be charged either as paid or at the prevailing rates if the organization carries its own risk.

Fixed charges are discussed further on page 9. A table of plant rental is included in the Appendix.

GENERAL EXPENSES.

The fourth element of cost is general expense. It often is called "overhead" or "burden," terms derived from factory cost keeping, the use of which in highway-cost keeping is not recommended.

General expense includes all charges that can not be connected directly with the cost of labor, material, and plant. For convenience in accounting and for the purpose of securing a desirable division of road cost, general expense will be considered as divided into two

classes. One will be referred to as "engineering and supervision" and will include those items of inspection and engineering which can be charged directly to the project. The other class will be referred to as "administration expense" and include those expenditures incurred in conducting all the activities of the department which are so general in character that they are not assignable directly to any particular project.

The desirability of separating the project cost of engineering and supervision from administration cost and unit costs will be apparent after a little consideration. The work of the engineer in preparing the plans and specifications affects labor and material costs only in the kinds and amounts that may be required and not at all in the efficiency of their expenditure. By carefully worked out profiles and cross-sections an engineer may reduce the yardage of excavation required, but such planning may not reduce the cost per unit of excavation. To secure efficiency in operations is the function of the superintendent or the foreman who is responsible for the cost of such operations. If engineering and supervision cost is incorporated in unit cost, an element is included over which the foreman or superintendent has no control, and his efficiency is obscured thereby. If, on the other hand, engineering and supervision cost is included in the charge for administration, it is placed in a class of expenditures over which the engineer has little or no control.

Highway administrative organizations are prescribed largely by statute and the attendant costs necessarily are dependent, in a large measure, upon the form of the organization, the various duties required, the methods of financing, and many other factors, all of which are conditions imposed by legislation. To include with these administrative costs the cost of project engineering and supervision would mean the loss of valuable comparable information on the efficiency of the divisions of an organization and one type of administrational organization with another.

Administration.—Administration costs include such expenditures as salaries and expenses of the executive officers, legal services, maintenance of office, departmental engineering, investigations, experiments, clerical staff, fiscal operations, and miscellaneous fixed charges. These expenditures can not be allocated directly to any particular class of work or to individual projects.

Cost accountants have devised numerous ways of distributing general expenses to the various classes of work. Most of these, however, are not practicable in the distribution of such expenses on road work. Since indirect labor and indirect materials are distributed directly in the unit costs, and engineering and supervision are chargeable directly to projects, the remaining portion of what would be considered "burden" by factory cost accountants is comparatively

small in proportion to the aggregate expenses. Any portion of general expense that can be assignable directly to a project should be charged against such project. The remainder should be prorated over all the project expenditures for the period.

Engineering and supervision.—To engineering and supervision should be charged all expenditures for surveys, plans, specifications, estimates, tests, and all engineering inspection and supervision in the nature of oversight required to secure the proper execution of the work. Such expenditures can be charged directly to individual projects.

FIXED CHARGES.

Fixed charges are those items of expense which go on practically unchanged irrespective of the activities of the organization. Those fixed charges which pertain to the production plant have been discussed in relation to plant and equipment. Certain fixed charges not immediately connected with production operations may best be considered as a part of general expense. Thus depreciation, interest, taxes, and insurance are elements of expense also in relation to the plant and equipment of the administrative organization, such as buildings, office and laboratory equipment, instruments, machines, and similar items.

In the practical application of cost keeping, fixed charges are considered only in so far as they aid in the determination of efficiency, and their inclusion as an item of cost is a question of accounting. Where fixed charges result from methods of financing rather than the methods of doing the work they belong to the field of bookkeeping and not cost keeping. Thus, where a county issues bonds for road improvement the interest is a fixed charge which must be paid and so increases the total outlay for the improvement but has no relation to the efficiency with which the work is executed, and is, therefore, a matter of bookkeeping and not cost keeping. Where two crews are engaged in excavation, one with power tools and the other with hand tools, fixed charges are of prime importance to the cost keeper for the purpose of determining efficiency and the cost of operation in each case.

It is customary among contractors to include all fixed charges as a part of the expense of work, and therefore they appear in the unit prices of their itemized bids. In making up his estimates on unit prices to check against submitted bids, the engineer therefore should include among other fixed charges interest on capital invested in plant and on necessary operating capital, for materials, pay roll, and deferred payments.

Considerations of fixed charges are also important in the selecting of equipment and determining upon types of improvements. These considerations are, however, within the field of engineering

economics and not cost keeping, although cost data have a most important part in the final determination.

HIGHWAY COST ANALYSIS.

An analytical chart has been prepared to place before the reader in concise and convenient form a summary of the foregoing discussion of cost elements applied to road work, and to show the relation between the cost elements and the final cost of the project as expressed in totals and by units. The first column of the chart contains the four basic elements of cost. Opposite each element, in the second column, are the classes of expenditure, such as direct, indirect, etc. The third column shows in detail the specific application of the cost. Example, "for materials," "for labor," "superintendence," etc. The fourth column contains a tabulation of the class of product resulting from the cost outlay, such, for example, as construction, maintenance, right of way, etc. The fifth column contains the final cost and presents it by units, by project, etc.

Highway cost analysis.

Elements of cost.	Classes of cost.	Application of cost.	Product of cost.	Summary of cost.
Highway cost....	Labor cost...	Direct..... Wages of laborers, mechanics, teamsters, etc.	Construction, maintenance, or reconstruction of road parts, right of way, grade and roadside, roadway, ditches, drains, bridges, and culverts, and supplementary parts.	By units, direct, as performed.
		Indirect... Wages and expenses of superintendents, foremen, timekeepers, guards, watchmen, water boys, etc., lost labor days, labor expense.		
	Material cost...	Direct..... Materials entering into product as integral parts.		
		Indirect... Supplies, used but not as a part of product.		
	Plant and equipment service cost.	Operating. Operation. Repairs. Idleness.		
		Fixed..... Depreciation. Interest. Taxes. Insurance.		
	General expense cost.	Project: Engineering and supervision. Salaries and expenses of engineers, field parties, draftsmen, inspectors, and clerks; office expenses, tests, and miscellaneous expenses for individual projects.	Plans, specifications, estimates, surveys, inspection, and direct supervision of work.	By project; upon completion may be apportioned to units.
		General: Administration. Salaries and expenses of executive, engineering, legal, and clerical staffs; expense of office maintenance, experiments, investigations, and fiscal operations; miscellaneous fixed charges.	General direction, policy, oversight, planning, control, legal, and financial provisions.	On all operations over a period of time and apportioned to projects.

UNITS OF MEASUREMENT.

Care should be taken in selecting the units on which to collect cost data. Too many and varied units will make the system cumbersome and expensive, while too few may impair its value seriously. Furthermore, the units of measurement adopted for any cost-keeping system or project must be definite, expressive, readily obtainable, and familiar. Thus, for example, the ton and the cubic yard as applied to broken stone are definite units and afford a ready and accurate comparison, but the square yard when applied to a finished macadam road is indefinite until additional information as to the depth of the material is available. Similarly, many units, such as wheelbarrow, wagon, truck, or carload, while often convenient units of count in the field, are indefinite and always should be reduced to definite comparable units, such as cubic yard or ton.

The units selected must, so far as possible, be expressive of definite operations. Thus, while in engineering construction the cubic yard is a very common unit upon which contract prices are based, it frequently is a very uncertain unit of performance, as it is a composite of other units. For example, in rock excavation there are involved the following operations: (1) Drilling, (2) blasting, (3) breaking large chunks; (4) loading into carts, wagons, cars, or the like, (5) transporting, (6) dumping.

The important item of drilling depends largely on the necessary spacing of the drill holes, which varies in the different kinds of rock and in different kinds of excavation. Clearly, then, the linear foot of drill holes is the unit for measuring the output of the drillers, and not the cubic yard. Transporting the rock is largely a function of distance; hence the unit of transportation cost should be the ton or yard carried 100 feet or 1 mile, and not the cubic yard without the factor of distance.

The units must be obtainable readily or the cost of collecting the necessary data will be too high. Thus, for example, to obtain the exact cubic yardage and the distance it was moved in preparing the subgrade for a macadam road with a road machine would be not only difficult, but expensive. Hence for this class of work the readily obtainable, though less definite, unit of the square yard usually is adopted.

That the full value of the cost-keeping system may be realized, the units in which the data are expressed must be familiar to those charged with their collection as well as to those who are to profit from their use. Thus, the cubic meter is as definite a unit for measuring earthwork and generally as readily obtainable as the cubic yard, but to the average roadman it has little or no meaning until translated into the terms in which he is accustomed to think. If

any one of two or more units otherwise would answer equally well, the one most familiar and generally used always should be adopted.

There are many units so closely related to the desired unit of measurement that with very little computation they can be transformed into the desired unit. For example, the knowledge of the number of bags or barrels of cement used and the proportion of the mixture of the concrete are functions which at once determine the amount of sand and stone used. A number of tables giving some of the more common and convenient units of measurement used in collecting and compiling cost data relating to road work, are given in the Appendix.

PART II.

COST KEEPING FOR HIGHWAY WORK.

ESSENTIALS OF A COST SYSTEM.

Certain fundamental principles must be followed to make any cost system successful. This applies to road costs as well as to factory costs. Any cost-keeping system to be successful must be (1) reliable, (2) simple, (3) immediate, (4) flexible, and (5) relatively inexpensive.

(1) Reliability is of paramount importance. If the data collected are not reliable, all records based upon them of course will be misleading and the results dangerous. Accuracy is desirable, but this need not be carried beyond the practical limits adopted for measuring the units of materials expended and the units of work accomplished.

(2) If simplicity be not maintained the purpose of the system will be defeated. Involved and complex forms are confusing to the recording officials, difficult to compile for study and analysis, and apt to be inaccurate and a useless expense.

(3) To be effective, the cost records must be susceptible of immediate analysis and must reach the officials responsible for the economic progress of the work in time to be of use. If a week or 10 days must elapse before wasteful methods and incompetency are discovered the information is past history and it may be too late to try other methods which might rectify the detrimental condition.

(4) Flexibility is very desirable. The system must be elastic enough to provide for the recording of all classes of work, irrespective of the size of the project, without any material change in the prescribed forms.

(5) Finally, the system must be relatively inexpensive. The cost of determining cost must be reduced to a minimum. If expense of obtaining cost records to point out the way to efficiency is not much below the saving effected, they have no just claim to a place in any plan of management.

CLASSIFICATION OF EXPENDITURES.

The first problem in developing a cost-keeping system for highway work is to devise a general classification of expenditures that will conform to accounts appearing upon the ledger of the organization; that is, at the outset the cost keeper's records must tie into the book-

keeper's accounts. The ledger, it is well to recall, contains only as debits the funds received or appropriated and as credits the payments made from those various funds summarized from a record which carries the distribution of these expenditures according to subheadings or primary accounts. It is usual to classify accounts as far as possible by departments, or with respect to certain functions for which funds are provided. Such a classification of accounts provides the first division for the cost keeper. This division gives what usually are known as the general accounts. Numbers or letters are used to represent these accounts, and in these letters or symbols we have the beginning of a code for cost keeping. The following classification and corresponding letters show a departmental division of accounts and a letter code suitable for highway work:

GENERAL ACCOUNTS.

C. CONSTRUCTION.—M. MAINTENANCE.—R. RECONSTRUCTION.—P. PLANT.—A. ADMINISTRATION.

The first three of these, it will be observed, have to do with certain road operations. It will be found upon analysis that they consist of the operations necessary to produce or preserve road parts. A subdivision of these general accounts produces what are called the primary accounts. Such a division is shown below. The accompanying numbers give a development of the cost-keeping code:

C, M, AND R. CONSTRUCTION, MAINTENANCE AND RECONSTRUCTION.

00 to 09. Right of way.
10 to 19. Grade and roadside.
20 to 29. Roadway.
30 to 39. Ditches and drains.
40 to 49. Bridges and culverts.
50 to 59. Supplementary parts.
60 to 69. Engineering and supervision.

P. PLANT.

70 to 79. Plant accounts.

A. ADMINISTRATION.

80 to 99. Administration accounts.

The numbers preceding the primary account give the range of class numbers for the final cost-keeping code. Thus 30 to 39 are the inclusive numbers for class costs of ditches and drains. This first division of the general accounts would serve very satisfactorily for a simple cost-keeping system. In such case the first set of numbers could be omitted and ditches and drains would be represented by 39 instead of the range of numbers from 30 to 39.

To obtain a system of class numbers for more detailed costs these primary accounts are further expanded as shown in the following table:

PRIMARY ACCOUNTS AND CLASS CODE.

C, M, AND R. CONSTRUCTION, MAINTENANCE, AND RECONSTRUCTION.

Right of Way.

00 Preliminaries.
01 Right-of-way surveys.
02 Right-of-way plans.
03 Real estate.
04 Damages.
09 Miscellaneous.

Grade and Roadside.

10 Cuts and embankments.
11 Shoulders.
12 Berms and slopes.
13 Trees, shrubs, grass, etc.
19 Miscellaneous.

Roadway.

20 Subgrade.
21 V drains.
22 Sub-base.
23 Base course.
24 Intermediate course.
25 Binder course.
26 Cushion course.
27 Top course.
28 Surface.
29 Miscellaneous.

Ditches and Drains.

30 Ditches and gutters.
31 Ditches and gutters, paved.
32 Blind drains.
33 Tile drains.
34 Catch basins.
35 Drainage channels.
39 Miscellaneous.

Bridges and Culverts.

40 Foundations.
41 Abutments.
42 Piers and bents.
43 Superstructures.
44 Box culverts.
45 Pipe culverts.
49 Miscellaneous.

Supplementary Parts.

50 Signs and sign posts.
51 Monuments.
52 Guard rails.
53 Curbs.
54 Retaining walls and parapets.
55 Riprap and revetments.
56 Roadside treatment.
59 Miscellaneous.

Engineering and Supervision

60 Location and relocation surveys.
61 Surveys (for operations).
62 Plans.
63 Specifications and contract preparation.
64 Estimates.
65 Expense of awards.
66 Office expenses, engineering.
67 Supervisory engineering.
68 Inspection and tests.
69 Miscellaneous.

P. PLANT AND EQUIPMENT.

70 Buildings, fixtures, and grounds.
71 Quarries, pits, material yards, etc.
72 Power tools and equipment.
73 Hand tools and equipment.
74 Livestock and vehicles.
75 Camp equipment.
76 Camp buildings and shelters.
77 Storage and transportation.
79 Miscellaneous.

} Primary Accounts.

PRIMARY ACCOUNTS AND CLASS CODE—Continued.

A. ADMINISTRATION.

80 Executive.	Primary Accounts.
90 Maintenance of office.	
92 Legal.	
94 Clerical.	
95 Fiscal.	
97 Engineering, departmental.	
99 Miscellaneous.	

NOTE.—It will be observed that no divisions beyond primary accounts have been provided under Plant and Administration. These can be expanded further to meet the requirements of the organization.

OPERATION CODE.

The next step is to develop a series of operations and a corresponding code which will include all the operations performed by the various departments to construct and maintain the works under their supervision. This may be accomplished in either of two ways. One is to list with each class of work all the operations that are performed under it. The other is to designate an operation by symbol and prefix this symbol with a class symbol, designating the class of work. By the first method such an operation as "rolling" would be listed under each roadway part and for both construction and maintenance. In the latter method, which is followed in this bulletin, "rolling" occurs only once in the operation code and the class code symbol is prefixed to give it the distinguishing classification. Thus any work can be indicated by combining a class code symbol and an operation code symbol.

The operation code consists of a list of descriptive phrases arranged alphabetically and designated by consecutive numbers following a dash or decimal point. This dash or decimal shows the linking together of the classification and operation codes. The operation code must include all operations necessary to be performed and the phrases must be limited to a single interpretation. The divisions of the primary and general accounts given previously form the class code. As these class code numbers represent road parts or departments of the organization, an accumulation of a number of operations for any particular road part or department is effected readily by grouping all of those having the same class number. Below is given a typical operation series for the general operations of construction, reconstruction, and maintenance of highways. A similar code could be devised for other operations.

THE OPERATION CODE.

-00 Assembling.
-01 Back filling.
-02 Blacksmithing.
-03 Blasting.
-04 Building.
-05 Building false work.
-06 Cleaning.
-07 Clearing.
-08 Clearing and grubbing.
-09 Cofferdamming.
-10 Cribbing.
-11 Curing concrete.
-12 Crushing.
-13 Dragging.
-14 Drilling.
-15 Drilling and blasting.
-16 Excavating borrow.
-17 Excavating common.
-18 Excavating earth.
-19 Excavating loose rock.
-20 Excavating solid rock.
-21 Excavating wet earth.
-22 Filling ruts.
-23 Filling washouts.
-24 Finishing.
-25 Forming.
-26 General.
-27 Grouting.
-28 Grubbing.
-29 Guarding.
-30 Harrowing.
-31 Hauling.
-32 Heating bituminous materials.
-33 Heating materials.
-34 Laying.
-35 Loading.
-36 Loading and hauling.
-37 Loosening.
-38 Mixing.
-39 Mixing and placing.
-40 Moving.
-41 Operating.
-42 Oiling.
-43 Painting.
-44 Patroling.
-45 Pile driving.
-46 Placing materials.
-47 Placing steel.
-48 Planting.
-49 Plumbing.
-50 Plowing.
-51 Pumping.
-52 Quarrying.
-53 Removing snow.
-54 Repairing.
-55 Riveting.
-56 Rolling.
-57 Scarifying.
-58 Screening.
-59 Shaping.
-60 Spreading bituminous materials.
-61 Spreading materials.
-62 Spreading screenings, sand, or chips.
-63 Sprinkling.
-64 Stripping.
-65 Tamping.
-66 Trimming.
-67 Washing.
-68 Washing and screening.
-69 Wasting materials.
-70 Water-proofing.
-71 Working on joints.
-72 Wrecking.

METHOD OF OBTAINING CLASS AND OPERATION NUMBER FROM CODE.

To procure a code number for any unit of work it is first decided what class of work is under consideration, and a number is selected from the class table. Then the specific operation is sought for in the second, or operation, table. The two are joined together with a hyphen or dash. The code letter of the department then may be prefixed to the first number and the classification symbol is complete.

If it be desired to know the code numbers to be used for recording the labor of a man mixing concrete for use as a road top course the class number for a road top course first is looked up in the class code (p. 15). This number is found to be 27; then the

operation "mixing" is taken from the operation code (p. 17) and found to be 38. Joining the two together with a dash produces the full code symbol 27–38. The letter "C" prefixed would indicate construction work, while the letter "M" would indicate a maintenance operation.

Usually no classification letter will be used, but instead the capital letter "C", "M", or "R" will be shown on the recording form. If it be desired to know what code symbol to use in order to indicate properly the time of a man spreading bituminous material on a road for maintenance purposes, the letter "M" is set down first to show that the work is that of maintenance. From the class code (p. 15) the number for a surface is found to be 28. Preceding this number with a capital letter "M" gives M–28, which shows that maintenance work has been done on a road surface. Then there is selected from the operation code (p. 17) the number for spreading bitumen, which is found to be 60. The code symbol for maintenance work of spreading bitumen on a road surface then will be M–28–60.

USE OF CODE IN OPERATIONS.

In actual use the cost keeper generally would obtain his data from the timekeeper, who would be charged with keeping time and costs. A code for use of the timekeeper would be prepared from the class and operation codes, which would have the advantage of being abbreviated and also properly arranged for the cost keeper's needs. Below is shown such a code, which was used on work where costs of the principal operations were desired, and also the expanded code, which was used where it was desired to make a more detailed study of operations for the purposes of efficiency.

TIMEKEEPER'S CODE.

ABBREVIATED.	EXPANDED.
(1)	*Grade and roadside.*
19–17 Grading—rough.	11 Shoulders: –56 Rolling. –58 Shaping. 19 Miscellaneous: –07 Clearing. –16 Excavating borrow. –17 Excavating common. –19 Excavating loose rock. –20 Excavating solid rock. –28 Grubbing. –31 Hauling. –35 Loading.

TIMEKEEPER'S CODE—Continued.

ABBREVIATED.	EXPANDED.
(2)	*Roadway.*
20–59 Grading—fine.	20 Subgrade: –56 Rolling. –59 Shaping. –63 Sprinkling.
(3) 23–26 Base course—general.	23 Base course: –12 Crushing. –31 Hauling. –35 Loading. –56 Rolling. –61 Spreading materials. –62 Spreading screenings, sand, and chips. –63 Sprinkling.
(4) 23–34 Base course—laying.	
(5) 23–56 Base course—rolling.	
(6) 23–62 Base course—spreading sand and chips.	
(7) 27–36 Top course—loading and hauling.	27 Top course: –31 Hauling. –32 Heating bituminous materials. –35 Loading. –56 Rolling. –60 Spreading bitumen. –61 Spreading materials. –62 Spreading screenings, sand, and chips.
(8) 27–34 Top course—laying.	
(9) 27–60 Top course—spreading bitumen.	
(10) 27–24 Top course—finishing.	
	23–06 Cleaning base.

The timekeeper had only ten code numbers for general use, but where detailed costs were desired in order to determine relative efficiency and to eliminate wasteful methods 28 code numbers were used.

DETAIL OF COST ACCOUNTS AND NECESSARY CODES.

The detail in which costs are recorded must be left to the judgment of the supervisor or engineer in charge of the work. Unnecessary refinements are not desirable, as they only increase the work of those who used the data. On the other hand, divisions that are too general and inclusive will prevent the study of results for the purpose of promoting efficiency. The use or final disposition of the data is the factor which should determine the necessary details.

For example, let it be assumed that a county engineer or superintendent desires costs on a brick road for the purpose of making reports on expenditures to the board of highway supervisors. In this case summary costs of completed parts probably would meet the requirements. The divisions would logically be the main divisions of the road and the costs would be collected by these divisions.

This would provide the simplest division and consequently the simplest code, which for the case assumed would be as follows:

COST DIVISIONS.

	Code.
Right of way	09
Grade and roadside (or grading)	19
Roadway (or surfacing)	29
Ditches and drains	39
Bridges and culverts	49
Supplementary parts	59
Engineering and supervision	69
Administration	99

The first and the last two of these divisions would be compiled from office data so that the cost keeper would be concerned with only five divisions of field data.

The next advanced step that would be desirable in many cases would be the cost of major operations divided by road parts. This would give information suitable for the comparison of results with work of a like character or with unit prices or estimates.

COST DIVISIONS.

Road part.	*Operation*	*Code.*
Right of way:		
Plans and surveys	General	01–26
Real estate		02–
Miscellaneous		09–
Grade and roadside:		
Miscellaneous	Clearing and grubbing	19–08
Miscellaneous	Excavation, common	19–17
Roadway:		
Subgrade	Shaping	20–59
Base course	Laying	23–34
Top course	Laying	27–34
Ditches and drains:		
Paved gutter	Excavating, common	31–17
Paved gutter	Laying	31–34
Tile drains	Laying	33–34
Catch basins	General	33–26
Bridges and culverts:		
Foundations	Excavating, common	40–17
Foundations	Piling driving	40–45
Foundations	General	40–26
Abutments	General	41–26
Superstructures	General	43–26
Miscellaneous		49–
Supplementary parts:		
Signs and sign posts	General	50–26
Guard rails	General	52–26
Curbs	General	53–26
Miscellaneous		59–

COST DIVISIONS—Continued.

Road part.	*Operation.*	*Code.*
Engineering and supervision:		
Supervisory engineering	General	67–26
Inspection	General	68–26
Miscellaneous		69–
Administration:		
Engineering, departmental		97–
Miscellaneous		99–

For the purpose of obtaining costs in more detail than is given in the foregoing, both the class and operation codes are susceptible of further divisions. In the following, divisions are made of the example chosen which are as complete as will generally be practical to use for highway cost keeping except in those cases where efficiency studies are desired.

COST DIVISIONS.

Road part.	*Operation.*	*Code.*
Right of way:		
Preliminaries		00–
Right-of-way surveys	General	01–26
Right-of-way plans	General	02–26
Real estate		03–
Damages		04–
Miscellaneous		09–
Grade and roadside:		
Cuts and embankments	Excavating, common	10–17
Cuts and embankments	Excavating, borrow	10–16
Cuts and embankments	Drilling	10–14
Cuts and embankments	Blasting	10–03
Cuts and embankments	Loading	10–35
Cuts and embankments	Hauling	10–31
Cuts and embankments	Wasting materials	10–69
Cuts and embankments	Rolling	10–56
Shoulders	Rolling	11–56
Shoulders	Shaping	11–59
Berms and slopes	Trimming	12–66
Berms and slopes	Planting	12–48
Miscellaneous	Clearing	19–07
Miscellaneous	Grubbing	19–28
Miscellaneous	Blasting	19–03
Roadway:		
Subgrade	Shaping	20–59
Subgrade	Sprinkling	20–63
Subgrade	Rolling	20–56
Base course	Loading and hauling	22–36
Base course	Forming	22–25
Base course	Mixing	22–38
Base course	Placing	22–46
Base course	Shaping	22–59
Cushion course	General	26–26
Top course	Loading and hauling	27–36

COST DIVISIONS—Continued.

Road part.	*Operation.*	*Code.*
Roadway—Continued.		
Top course	Laying (brick)	27–34
Top course	Rolling (brick)	27–56
Top course	Grouting	27–27
Top course	Curing concrete	27–11
Miscellaneous	Cleaning	29–06
Ditches and drains:		
Ditches and gutters	Excavating, common	30–17
Ditches and gutters paved	Forming	31–25
Ditches and gutters paved	Loading and hauling	31–36
Ditches and gutters paved	Mixing and placing	31–39
Ditches and gutters paved	Finishing	31–24
Ditches and gutters paved	Curing concrete	31–11
Tile drains	Excavating, common	33–17
Tile drains	Laying	33–34
Tile drains	Loading and hauling	33–36
Tile drains	Tamping	33–65
Tile drains	Back filling	33–01
Catch basins	Excavating, common	34–17
Catch basins	Loading and hauling	34–36
Catch basins	Laying (brick)	34–34
Bridges and culverts:		
Foundations	Cofferdaming	40–09
Foundations	Cribbing	40–10
Foundations	Excavating, common	40–17
Foundations	Excavating, wet	40–21
Foundations	Forming	40–25
Foundations	Loading and hauling	40–
Foundations	Pumping	40–51
Foundations	Pile driving	40–45
Foundations	Mixing and placing (concrete)	40–39
Foundations	Back filling	41–01
Abutments	Loading and hauling	41–36
Abutments	Laying (masonry)	41–34
Abutments	Pumping	41–51
Abutments	Quarrying (masonry)	41–52
Piers and bents	(Same operations as abutments)	42–
Superstructures	Blacksmithing	43–02
Superstructures	Building false work	43–05
Superstructures	Curing concrete	43–11
Superstructures	Finishing	43–24
Superstructures	Forming	43–25
Superstructures	Loading and hauling	43–36
Superstructures	Mixing and placing (concrete)	43–39
Superstructures	Placing steel	43–47
Box culverts	Excavating, common	44–17
Box culverts	Loading and hauling	44–36
Box culverts	Forming	44–25
Box culverts	Mixing and placing	44–39
Box culverts	Curing concrete	44–11
Pipe culverts	Back filling	45–01

COST DIVISIONS—Continued.

Road part.	*Operation.*	*Code.*
Bridges and culverts—Continued.		
Pipe culverts	Excavating, common	45–17
Pipe culverts	Forming (headwalls)	45–25
Pipe culverts	Laying (pipe)	45–34
Pipe culverts	Loading and hauling	45–36
Pipe culverts	Mixing and placing	45–39
Miscellaneous	Cleaning	49–06
Supplementary parts:		
Signs and signposts	Building	50–04
Signs and signposts	Loading and hauling	50–36
Signs and signposts	Painting	50–43
Monuments	General	51–26
Guardrails	Building	52–04
Guardrails	Loading and hauling	52–36
Guardrails	Painting	52–43
Curbs	Back filling	53–01
Curbs	Curing concrete	53–11
Curbs	Excavating, common	53–17
Curbs	Finishing	53–24
Curbs	Forming	53–25
Curbs	Mixing and placing	53–39
Riprap and revetments	Loading and hauling	55–46
Riprap and revetments	Placing materials	55–46
Roadside treatment	Clearing	56–07
Roadside treatment	Loading and hauling	56–36
Roadside treatment	Planting	56–48
Roadside treatment	Painting	56–43
Engineering and supervision:		
Location and relocation surveys	General	60–26
Surveys for operations	General	61–26
Plans	General	62–26
Specifications and contracts	General	63–26
Estimates	General	64–26
Expense of awards	General	65–26
Office expenses engineering	General	66–26
Supervisory engineering	General	67–26
Inspection	General	68–26
Miscellaneous		69–
Plant and equipment:		
Quarries, pits, etc	General	71–26
Camp buildings and shelters	General	76–26
Storage and transportation	General	77–26
Miscellaneous	Assembling	79–00
Miscellaneous		79–
Administration:		
Engineering		97–
Miscellaneous		99–

RECORDING FORMS.

Standard forms, to record the daily expenditures of labor, materials, and plant service, should be prepared for the use of the timekeepers or foremen responsible for reports. The use of nondescript

forms or blank books should not be permitted, as such practice will result in unreliable data, often estimated at the end of the day's work, or a jumble of meaningless figures. Forms to be used for recording field data should be reduced, if possible, to pocket size for the sake of convenience. Two such forms are suggested in this bulletin, the sheets being 4¾ inches wide by 10½ inches long. It is not expected that these forms will meet all the requirements for every system, but it is believed that they are correct in principle, and with slight modifications will be found applicable for any organization doing highway work.

The forms designed and suggested herein are based upon and developed from the great number of various forms now in use in highway work throughout the United States and Canada. The same form is used for labor and equipment operations, but an additional form is necessary for materials, as it would be awkward to make out individual sheets for each kind of material. The daily summary of costs, and the periodic and total summary cost sheets are included, to show the final disposition and use of the data collected on the daily record forms. The final summaries also will fulfill the purpose of a final record of the cost of any job, and can be published for the purpose of substantiating and justifying the amounts expended.

Additional forms are necessary to record progress and character of the work by the supervising engineer, and the methods and amounts of payments made upon the work. Such forms will be treated in a subsequent bulletin.

The cost-recording forms are outlined and used as follows:

Form No. 2 (fig. 2) provides for 40 entries of men or equipment or both and their use on six classifications. The amount for each individual item can be given both in money and in total hours.

This form shows that on August 29, 1917, the foreman F. Smittie employed a gang of laborers numbered from 1 to 21; engineer, No. 4; rollers, No. 1 and No. 2; team, No. 2; guards Nos. 1 and 2; and waterboy, No. 2, on reconstruction work on the B. and W. Road, section 4.

These codes show they were employed as follows:

11–59 Grade and roadside, shoulders, shaping.
23–06 Roadway, base course, cleaning.
23–56 Roadway, base course, rolling.
23–61 Roadway, base course, spreading.
27–34 Roadway, top course, laying.
27–56 Roadway, top course, rolling.

DAILY TIME AND COST RECORD

ROAD. B & W. SECTION 4 8/29/17 DATE

LOCATION On Road ~~G.M.~~ R.

LABOR OR EQUIPMENT	TIME ON	TIME OFF	HRS.	RATE	TOTAL AMOUNT	CODE 11-59 HRS.	CODE 11-59 AMT.	CODE 23-06 HRS.	CODE 23-06 AMT.	CODE 27-34 HRS.	CODE 27-34 AMT.
F. Smittie	7.00	5.00			4 40						
Laborer 1	"	4.30	8½	.375	3 19					IIII½	3 19
2	"	"	"	"	3 19					IIII½	3 19
3	"	"	"	"	3 19					IIII½	3 19
4	"	"	"	"	3 19					IIII½	3 19
5	"	"	"	"	3 19					IIII½	3 19
6	"	"	"	"	3 19					IIII½	3 19
7	"	"	"	"	3 19					IIII½	3 19
8	"	"	"	"	3 19					IIII½	3 19
9	"	"	"	"	3 19					IIII½	3 19
10	"	"	"	"	3 19					IIII½	3 19
11	"	"	"	"	3 19					IIII½	3 19
Sent to Rosetta 12	"	4.00	8	"	3 00	II	75	I	37	III	1 88
13	"	"	"	"	3 00					IIII	3 00
14	"	"	"	"	3 00					IIII	3 00
15	"	"	"	"	3 00	III	1 88	I	37	II	75
16	"	5.00	9	"	3 37					IIII	3 37
17	"	"	"	"	3 37	IIIII	3 37				
			TOTAL				6 00		74		47 09
						23-56		23-61		27-56	
Sent to Rosetta 18	"	9.00	2	.375	75			II	75		
19	"	"	"	"	75			II	75		
20	"	"	"	"	75			II	75		
21	"	"	"	"	75			II	75		
Engineer 4	"	5.00	8	.50	4 00	III	1 50			III	2 50
Roller 1	"	"			5 00	III	5 00				
" 2	"	"			5 00					III	5 00
Team 2	10.00	12.00	2		1 50	I	75			I	75
Guard 1	7.00	5.00	9		2 80						
" 2	"	"	9		2 80						
Waterboy 2	"	"	9		88	Half time to Rosetta					
			TOTAL				7 25		3 00		8 25
			Mixing Plant closed down at 4 P.M.								
			Gang sent to Rosetta								
			TOTAL		83 21						

FIG. 2.

DAILY TIME AND COST RECORD

ROAD B & W. SECTION 4 8/29/17 DATE

LOCATION On Road ~~C.M.~~ R.

LABOR OR EQUIPMENT		TIME ON	TIME OFF	HRS	RATE	TOTAL AMOUNT	CODE 19-17 HRS.	CODE 19-17 AMT.	CODE 22-61 HRS.	CODE 22-61 AMT.	CODE 23-61 HRS.	CODE 23-61 AMT.
F. Rosetta		7.00	5.00			3 75						
Laborer	22	"	"	9	.375	3 37	IIII 1	2 25	III	1 12		
	23	"	"	"	"	3 37	IIII 1	2 25	III	1 12		
	24	"	"	"	"	3 37	IIII II	2 62	II	75		
	25	"	"	"	"	3 37	IIII II	2 62	II	75		
	26	"	"	"	"	3 37	IIII IIII	3 37				
	27	"	"	"	"	3 37	IIII IIII	3 37				
	28	"	"	"	"	3 37	IIII IIII	3 37				
	29	"	"	"	"	3 37	IIII IIII	3 37				
	30	"	"	"	"	3 37	IIII IIII	3 37				
	31	"	"	"	"	3 37	IIII IIII	3 37				
From Smittie's Gang	18	9.00	"	7	"	2 62					IIII II	2 62
	19	"	"	"	"	2 62					IIII II	2 62
	20	"	"	"	"	2 62	III	1 12	III	1 12	1	37
	21	"	"	"	"	2 62	III	1 12	III	1 12	1	37
From Carter's Gang	32	10.00	"	6	"	2 25	IIII 1	2 25	TOTAL 5 98			
	33	"	"	"	"	2 25	IIII 1	2 25				
	34	"	"	"	"	2 25	IIII 1	2 25				
	35	2.00	"	3	"	1 12	III	1 12				
From Smittie's Gang	11	4.00	"	1	"	37	1	37				
	12	"	"	"	"	37	1	37				
	13	"	"	"	"	37	1	37				
	14	"	"	"	"	37	1	37				
	15	"	"	"	"	37	1	37				
	1	4.30	"	½	"	18	½	18				
	2	"	"	"	"	18	½	18				
	3	"	"	"	"	18	½	18				
	4	"	"	"	"	18	½	18				
	5	"	"	"	"	18	½	18				
	6	"	"	"	"	18	½	18				
	7	"	"	"	"	18	½	18				
	8	"	"	"	"	18	½	18				
	9	"	"	"	"	18	½	18				
	10	"	"	"	"	18	½	18	22-56			
Engineer	2			6	.666	4 00	IIII	3 33	1	67		
Roller	3			6	.833	5 00	IIII	4 17	1	83		
									TOTAL 1 50			
Waterboy	2					87	Half time with Smittie					
			TOTAL			69 32		51 22				5 98

FIG. 3.

DAILY TIME AND COST RECORD

ROAD Route 2. SECTION A. 8/24/17 DATE

LOCATION On Road C. ~~M.R.~~

LABOR OR EQUIPMENT	TIME ON	TIME OFF	HRS	RATE	TOTAL AMOUNT	CODE 11-59 HRS.	CODE 11-59 AMT.	CODE 20-59 HRS.	CODE 20-59 AMT.	CODE HRS.	CODE AMT.
A8	7.00	6.00	10	.625	6 25						
Laborer 174	"	8.30	1½	.375	55	1½	55	Fired			
187	9.30	2.30	4	"	1 50	IIII	1 50	Fired			
188	"	"	4	"	1 50	IIII	1 50	Sent to Tool House			
189	"	6.00	7½	"	2 80			IIII½	2 80		
197	"	2.30	4	"	1 50	IIII	1 50	Sent to Tool House			
199	"	6.00	7½	"	2 80			IIII½	2 80		
408	7.00	"	10	"	3 75			IIII	3 75		
414	8.00	"	9	"	3 37	IIIII	3 37				
431	7.00	"	10	"	3 75			IIII	3 75		
432	"	"	10	"	3 75			IIII	3 75		
437	11.00	"	6	"	2 25	II I	2 25				
439	7.00	"	10	"	3 75			IIII	3 75		
440	"	"	10	"	3 75			IIII	3 75		
448	"	"	10	"	3 75	IIII	3 75				
454	"	"	10	"	3 75	IIII	3 75				
465	"	"	10	"	3 75	II I	2 25	IIII	1 50		
469	"	"	10	"	3 75	IIII	3 75				
470	"	"	10	"	3 75	II	1 87	II	1 88		
475	"	"	10	"	3 75	IIII	3 75				
477	"	8.30	1½	"	55	1½	55	Sent to Steam Shovel 2			
478	"	6.00	10	"	3 75			IIII	3 75		
479	"	"	10	"	3 75	IIII	3 75				
484	"	8.30	1½	"	55	1½	55	Sent to Steam Shovel 2			
485	"	"	1½	"	55	1½	55				
486	"	"	1½	"	55	1½	55				
487	"	9.30	2½	"	93	1½	93	Fired			
495	"	8.30	1½	"	55	1½	55	Sent to Steam Shovel 2			
500	"	4.00	8	"	3 00			IIII	3 00		
501	"	8.30	1½	"	55	1½	55	Sent to Steam Shovel 2			
506	"	6.00	10	"	3 75	Carrying Water					
532	"	"	10	"	3 75	IIII	3 75				
568	11.00	"	6	"	2 25	II I	2 25				
599	"	12.00	1	"	37	1	37	Sent to Tool House			
195	"	2.30	1½	"	55			1½	55	Sent to Tool House	
Team 21	7.00	12.00	5	.80	4 00			II	4 00		
" 22	"	"	5	"	4 00			II	4 00		
Grader	"	"	5	.50	2 50			II	2 50		
		TOTAL			99 67	44 14		45 53			

FIG. 4.

ROAD Ashland-Lexington
SECTION Cemetery Bridge.

DAILY RECORD OF MATERIALS AND SUPPLIES

B. Messing.. FOREMAN
C.M.R.

DATE Sept. 19. 1910..

KIND	UNIT	RATE	CODES, UNITS, AND AMOUNTS															
			43-39			41-39			43-25			43-47						
			UNITS	AMOUNT		UNITS	AMOUNT		UNITS	AMOUNT		UNITS	AMOUNT		UNITS	AMOUNT	UNITS	AMOUNT
Cement	Bag	.47	150	70	50	10	4	70										
Lumber	M	30.00							1.2	36	00							
Nails	lb.	.035							20		70							
Wire	lb.	.035							10		35	8		28				
Gasoline	Gal.	.20	5	1	00	1		20										
Sand	C.Y.	.60	22	13	20	2	1	20										
Steel	lb.	.03										7800	234	00				
Oil					10													
TOTAL AMOUNTS				84	80		6	10		37	05		234	28				
WHERE USED			West Span			East Abutment			West Span			3 West Spans						

FIG. 5.

Notes on the sheet show that four laborers were transferred to foreman Rosetta at 9 a. m. and a large part of the crew between 4 and 4.30 p. m.

The daily record of foreman Rosetta's crew (fig. 3) shows on the same road a crew of 33 laborers, a water boy, roller, and engineer on classifications—

19–17 Grade and roadside, miscellaneous, excavating, common.
22–56 Roadway, sub-base course, rolling.
22–61 Roadway, sub-base course, spreading.
23–61 Roadway, base course, spreading.

Laborers were received three times during the day from foreman Smittie and once from foreman Carter.

In figure 4 is shown the work of a large crew, but on only two operations. A number of changes in the crew will be observed. Only 15 men out of a total of 36 employed worked the full day with foreman A8.

MATERIAL AND SUPPLIES.

The form for materials and supplies (fig. 5) is the same size as that for labor and equipment and may be carried by the timekeeper or foreman in the same book or binder with the other form. The material form is for one day only and 12 different materials may be recorded on a single sheet. The sheet shows distribution as follows:

FOR OPERATION 43–39, MIXING AND PLACING SUPERSTRUCTURE.

150 bags cement, at $0.47	$70.50
5 gallons gasoline, at $0.20	1.00
22 cubic yards sand, at $0.60	13.20
Oil	.10
Total for operation (used on west span)	84.80

FOR OPERATION 41–39, MIXING AND PLACING ABUTMENT.

10 bags cement, at $0.47	$4.70
1 gallon gasoline, at $0.20	.20
2 cubic yards sand, at $0.60	1.20
Total for operation (used on east abutment)	6.10

FOR OPERATION 43–25, FORMING SUPERSTRUCTURE.

1,200 feet b. m. lumber, at $0.03	$36.00
20 pounds nails, at $0.035	.70
10 pounds wire, at $0.035	.35
Total for operation (used on west span)	37.05

FOR OPERATION 43–47, SUPERSTRUCTURE, PLACING STEEL.

8 pounds wire, at $0.035	$0.28
7,800 pounds steel, at $0.03	234.00
Total for operation (used on 3 west spans)	234.28

These data are combined and arranged on the daily report of costs form (fig. 9) so as to make possible the ready determination of unit costs. In this case no indirect labor cost is charged to equipment. Teams were used only for hauling and were required to make a certain number of trips per day.

The amount of work done was reported to the superintendent by the engineer in charge of this division of the work.

DAILY TIME AND COST RECORD

ROAD Route 2 SECTION A 8/25/17 DATE

LOCATION 40+75 to 45+00 C. ~~M.R.~~

LABOR OR EQUIPMENT	TIME ON	TIME OFF	HRS	RATE	TOTAL AMOUNT		CODE 23-34 HRS	CODE 23-34 AMT.		CODE 20-59 HRS.	CODE 20-59 AMT.		CODE 23-12 HRS.	CODE 23-12 AMT.	
F. Waugh	7.00	6.00	10	.75	7	50									
Laborer 592	"	"	"	.412	4	12	IIII IIII	4	12						
601	"	"	"	"	4	12	IIII I	2	47				IIII	1	65
610	"	"	"	"	4	12	IIII	2	06				IIII	2	06
590	"	"	"	"	4	12	IIII	2	06				IIII	2	06
589	"	"	"	"	4	12	III	1	24	III	1	24	IIII	1	64
533	"	"	"	"	4	12	IIII	2	06				IIII	2	06
546	9.00	"	8	"	3	30	IIII	2	06	III	1	24			
481	10.00	"	7	"	2	88	IIII I	2	47	I		41			
474	7.00	"	10	"	4	12	IIII IIII	4	12						
473	"	"	"	"	4	12	IIII III	3	30				II		82
467	"	"	"	"	4	12	IIII III	3	30				II		82
466	"	"	"	"	4	12	IIII III	3	30	II		82			
422	10.00	"	7	"	2	88	IIII II	2	88						
					TOTAL		86	35	44						
							11-59								
420	7.00	6.00	10	.412	4	12	IIII I	2	47	III	1	24	I		41
425	"	"	"	"	4	12	IIII III	3	30	II		82			
					TOTAL		14	5	77	14	5	77	28	11	52
							23-56			23-31					
Team 9	7.00	6.00	10	.80	8	00				IIII IIII	8	00			
12	"	"	"	"	8	00				IIII IIII	8	00			
15	"	"	"	"	8	00				IIII IIII	8	00			
16	"	"	"	"	8	00				IIII IIII	8	00			
17	"	"	"	"	8	00				IIII IIII	8	00			
18	"	"	"	"	8	00				IIII IIII	8	00			
23	"	"	"	"	8	00				IIII IIII	8	00			
Waterboy 115	"	"	"	.275	2	75									
Engineer 169	"	"	"	.625	6	25	IIII IIII	6	25						
Roller 13		Day			8	00	Day	8	00						
Team 5	8.00	6.00	9	.80	7	20				IIII III	7	20			
19	"	"	"	"	7	20				IIII III	7	20			
21	"	"	"	"	7	20				IIII III	7	20			
25	"	"	"	"	7	20				IIII III	7	20			
30	"	"	"	"	7	20				IIII III	7	20			
3	2.00	3.00	1	"		80	1		80						
					TOTAL		11	15	05	115	92	00			
			TOTAL		175	80									

FIG. 7.

ROAD Route 2 SECTION A

DAILY RECORD OF MATERIALS AND SUPPLIES

DATE 8/25/17 F. Waugh FOREMAN C.M.R.

KIND	UNIT	RATE	CODES, UNITS, AND AMOUNTS													
			23-34		23-56											
			UNITS	AMOUNT	UNITS	AMOUNT	UNITS	AMOUNT	UNITS	AMOUNT	UNITS	AMOUNT	UNITS	AMOUNT	UNITS	AMOUNT
Fld Stone	C.Y.	.25	87	21 75												
Coal	Ton	4.00			.25	1 00										
TOTAL AMOUNTS				21 75		1 00										
WHERE USED.			43+75 to 41+50		45+00 to 41+00											

FIG. 8.

DAILY REPORT OF COSTS

C.~~M.F.~~

ROAD Route 2 SECTION A WEATHER Clear-Warm FOREMAN F. Waugh DATE 8-25-17

CODE NUMBERS	LABOR				EQUIPMENT				MATERIALS & SUPPLIES					LABOR EQUIPMENT SUPPLIES MATERIALS	UNITS OF WORK COMPLETED		UNIT COST	LOCATION
	KIND	HOURS	RATE	AMOUNT	KIND	HOURS	RATE	AMOUNT	KIND	UNIT	NUMBER	RATE	AMOUNT		NUMBER	UNIT		
11-59	Labor	14	412	5 77														
	Indirect			94										6 71	300	Per foot of road	022	43+75 to 40+70
																	013	sq. yd. of roadway
20-59	Labor	14	412	5 77														43+75 to 40+75
	Indirect			94										6 71	533.3	sq. yds.	013	16 ft. wide
23-12	Labor	28	412	11 52														43+75 to 41+48
	Indirect			189										13 41	404	sq. yds.	033	16 ft. wide
23-34	Labor	86	412	35 44					Fld Stone	C.Y.	87	25	21 75					43+75 to 41+48
	Indirect			5 80										62 99	404	sq. yds.	156	16 ft. wide
23-31					Teams	115	80	92 00						92 00	404	sq. yds.	228	43+75 to 41+48
23-56	Engineer	10	625	6 25	Team	1	80	80	Coal	Ton	.25	4 00	1 00					45+00 to 41+00
	Indirect			67	Roller	day		8 00						16 72	711	sq. yds.	024	16 ft. wide
Totals		152		74 99				100 80					22 75	198 54	Per sq. yd. riding		467	
Indirect	Foreman	10	75	7 50	Basis for distribution of Indirect labor expenses on direct labor costs													
	Ht. Boy	10	275	2 75														
	Labor	152	0674	10 25														

FIG. 9.

REPORT OF PROGRESS AND COST.

Road No. 144—Sections A. Construction. Period from Mar. 1 to 15, 1917.

Code Nos.	Classification.	Unit.	For this period.			Summary to date.			Completed.
			Units completed.	Total cost.	Unit cost.	Units completed.	Total cost.	Unit cost.	
	Right of way:								*Per cent.*
01–26	Plans and surveys, general						$400.00		100
02	Real estate	Acre	10	$500.00	$50.00	25	1,500.00	60.00	80
09	Miscellaneous			600.00			1,200.00		85
	Grade and roadside:								
19–08	Clearing and grubbing	Acre	4	160.00	40.00	19	950.00	50.00	57
19–17	Miscellaneous, excavation, common	Cubic yard	500	150.00	.30	2,000	500.00	.25	50
	Roadway:								
20–59	Subgrade, shaping	Square yard	1,200	36.00	.03	16,000	64.00	.04	10
23–34	Base course, laying	do	1,000	900.00	.90	16,000	14,400.00	.90	10
27–34	Top course, laying	do	1,600	960.00	.60	1,600	960.00	.40	1
	Ditches and drains:								
31–17	Paved gutter, excavation, common	Linear foot	400	8.00	.02	1,000	30.00	.03	6
31–34	Paved gutter, laying	do	200	80.00	.40	800	320.00	.40	5
33–34	Tile drains, laying	do	50	15.00	.30	50	15.00	.30	2
33–26	Catch basins, general		2	40.00	20.00	3	60.00	22.00	25
	Bridges and culverts:								
40–17	Foundations, excavation, common	Cubic yard	2,000	1,600.00	.80	3,000	2,400.00	.80	80
40–45	Foundations, piling, driving	Linear foot	1,200	480.00	.40	2,000	1,000.00	.50	45
40–26	Foundations, general	Cubic yards	125	1,457.50	11.50	125	1,457.50	11.50	80
41–26	Abutments, general	do	400	3,600.00	9.00	400	3,600.00	9.00	60
43–26	Superstructures, general	do	120	1,920.00	16.00	120	1,920.00	16.00	
49–26	Bridges and corrugated pipe culverts, general	Linear foot	150	300.00	2.00	150	300.00	2.00	40
	Supplementary parts:								
50–26	Signs and sign posts, general		75	150.00	2.00	100	210.00	2.10	50
52–26	Guardrails, general	Linear foot	100	100.00	1.00	300	300.00	1.00	40
53–26	Curbs, general	do	1,000	200.00	.20	2,000	450.00	.22½	20
59–26	Monuments, general		10	30.00	3.00	10	30.00	3.00	40
	Engineering and supervision:								
67–26	Supervisory engineering, general			60.00			300.00		
68–26	Inspection, general			100.00			500.00		
69–	Miscellaneous			10.00			15.00		
	Total expenditures			13,456.00			32,887.50		

COST COMPILATION.

Road No. ....
Sections.............
Work begun.........
Completed...........

......................Superintendent.

Construction.
Maintenance.
Reconstruction.

Date.		Source of Item.	Right of way.			Grade and Roadside.		Roadway.			Ditches and drains.				Bridges and culverts.						Supplementary parts.				Engineering and supervision.			Admin-istra-tion.		To-tals.
Mo.	Day.		01–26	02–	09–	19–08	19–17	20–59	23–34	27–34	31–17	31–34	33–34	33–26	40–17	40–45	40–26	41–26	43–26	49–	50–26	52–26	53–26	59–26	67–26	68–26	69–	97–	99–	
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This form will be found very useful for the purpose of compiling costs. The data on the "Daily Reports of Costs" may be recorded each day and at any period the total costs by items may be obtained readily by adding the cost items already collected.

FINAL COST SUMMARY.

Road .....
Sections .....
.....
Sup't.

Cost of Construction .....
Date of Acceptance.....

[Items including cost of labor, materials, supplies, and rental of equipment.]

Road part.	Operation.	Code.	Units.	Unit cost.	Cost.	Total cost.	Percentage of whole cost.
							Per cent.
Right of way:							
Plans and surveys	General	01–26	Acres				
Real estate		02–	do				
Miscellaneous		09–	do				
Grade and roadside:							
Miscellaneous	Clearing and grubbing	19–08	do				
Miscellaneous	Excavation, common	19–17	Cu. yd				
Roadway:							
Subgrade	Shaping	20–59	Sq. yd				
Base course	Laying	23–34	do				
Top course	Laying	27–34	do				
Ditches and drains:							
Paved gutter	Excavation, common	31–17	Lin. ft				
Paved gutter	Laying	31–34	do				
Tile drains	Laying	33–34	do				
Catch basins	General	33–26	Only				
Bridges and culverts:							
Foundations	Excavation, common	40–17	Cu. yd				
Foundations	Piling, driving	40–45	Lin. ft				
Foundations	General	40–26	Cu. yd				
Abutments	General	41–26	do				
Superstructures	General	43–26					
Miscellaneous		49–					
Supplementary parts:							
Signs and sign posts	General	50–26	Lin. ft				
Guard rails	General	52–26	do				
Curbs	General	53–26	do				
Miscellaneous		59					
Engineering and supervision:							
Supervisory engineering	General	67–26					
Inspection	General	68–26					
Miscellaneous		69					
Administration:							
Engineering, departmental		97					
Miscellaneous		99					
Grand total							

DEFINITIONS OF OPERATION TERMS.

In road work it is not uncommon to find that the same operations are designated by different terms in different sections of the country. It has been thought advisable, therefore, to define briefly the processes which should be included by the cost keeper under each operation. Some of these operations will be found to overlap somewhat under certain conditions. This slight overlapping, however, seems preferable to the present ambiguity in the meaning of many of our road terms. Adherence to the following definitions will serve, therefore, to make such cost data as are collected more nearly comparable, regardless of locality. The several operations are defined in terms of the processes which they include.

Assembling.—Shall include all bringing together or collecting of tools and equipment, setting up of machinery, portable shacks, and all other structures where the parts are delivered "knocked down" and require only bolting or riveting together.

Back filling.—Shall include all processes of refilling excavations or filling against the back of abutments, walls, etc.

Blacksmithing.—Shall include all processes of working or shaping metals, except riveting, and shall include also such work in repairing the metal parts of machinery and equipment.

Blasting.—Shall include all methods of rending or loosening of rock, earth, or other material with an explosive.

Building.—Shall include the making, erecting, and establishing of buildings, structures, or parts, except bridges or portable structures delivered cut to fit.

Building false work.—Shall include the building or erecting of all temporary supports and bracing necessary for the erection of structures.

Cleaning.—Shall include all removal of dirt or débris by any means from the surfaces of roadways or from ditches, drains, culverts, etc., and shall include the sweeping of all road surfaces. It shall be applied also to the operations necessary to remove deleterious matter or coatings from the surfaces of such structures as bridges, buildings, guard rails, etc.

Clearing.—Shall include the freeing of the roadway and roadside of all vegetation or incumbrances.

Clearing and grubbing.—Shall include in addition to clearing, as defined above, the removal and disposal of stumps.

Cofferdamming.—Shall include only the building of cofferdams.

Cribbing.—Shall include the building of all kinds of timber cribs to retain or sustain earth work.

Curing concrete.—Shall include the careful protection and slow drying of concrete, to prevent cracking or injury of any kind until the concrete has hardened.

Crushing.—Shall include all reducing of stone or other material to small particles by pounding or squeezing, whether the work be done by machine or hand.

Dragging.—Shall include the smoothing of a roadway surface or the shaping and partial compacting of road courses with a road drag.

Drilling.—Shall include the piercing or boring of any material, as iron or rock, with drills operated by hand or driven by power.

Drilling and blasting.—Shall include, in addition to the drilling, the loading of the holes with an explosive and the detonation of the explosive charge.

Excavating.—Shall include the grading of the roadway, ditches, and slopes, and also the hollowing out by cutting or digging of all excavations for drainage structures.

Filling ruts.—This operation needs no explanation.

Filling washouts.—This operation needs no explanation.

Finishing.—Shall include all other work necessary to complete a road or part of a roadway.

Forming.—Shall include the building of all forms for concrete work and the removal of the same.

General.—Shall include all charges impossible to allocate directly as belonging to any other operation in the table, or as a summary of operations on particular posts when desired.

Grouting.—Shall include all filling out and finishing of any work with a thin watery cement, or cement and sand mixture, as the grouting of brick pavements, etc.

Grubbing.—Shall include the removal of stumps and roots.

Guarding.—Shall include all charges for watchmen, barriers, signs, and warning lights during the period that the road is being constructed or repaired.

Harrowing.—Shall include all methods of breaking up clods of material on the road or mixing with harrows the materials of which the road is to be made. It differs from loosening.

Hauling.—Shall include the transportation of materials or equipment.

Heating.—Shall include all processes of raising the temperature of materials by the application of heat.

Laying.—Shall include the coating, spreading over, or covering any roadway course or road surface with any material, the placing in definite position of similar individual pieces of prepared material, or the constructing of a roadway course.

Loading.—Shall include the placing of any object or material in a conveyance.

Loading and hauling.—Shall include a combination of loading and hauling, both of which have been defined.

Loosening.—Shall include the breaking up of a dense, close mass, as an old road surface, into detailed particles with picks, scarifiers, or any other equipment.

Mixing.—Shall include all blending of materials into masses by stirring or turning, such as the mixing of concrete, water, aggregate, etc., but shall not include harrowing.

Mixing and placing.—Shall include, in addition to mixing, the locating of the mixed material in a desired position.

Moving.—Shall include all operations necessary for shifting or changing the position of any object. Thus it is a general term and may include a number of specific operations.

Operating.—Shall include the continuing in activity of any machinery.

Oiling.—Shall include the spraying or coating of a road surface with liquid bituminous matter.

Painting.—Shall include the covering of any object with a coating of a prepared pigment; also shall include whitewashing.

Patroling.—Shall include the continuous services of patrolmen repairing and maintaining a designated stretch of road.

Pile driving.—Shall include the placing of piles or sheathing by means of a driving hammer.

Placing.—Shall include the locating in a desired position of any object or material.

Planting.—Shall include the putting or placing of any sod, seed, shrub, or tree for growth.

Plumbing.—Shall include the preparation and placing of pipes, pumps, etc., required to deliver water to the road.

Plowing.—Shall include the loosening of any material by the use of a plow.

Pumping.—Shall include the lifting or driving of any material by pumps.

Quarrying.—Shall include the taking out of stone from an excavation or quarry.

Removing snow.—Requires no explanation.

Repairing.—Shall include all acts of returning to a sound state any road part where the work done is not extensive enough to be classified as reconstruction.

Riveting.—Shall include the uniting of two or more pieces with rivets and the heading of the rivets.

Rolling.—Shall include all compressing of roadway or surface material with a hand, horse, or power roller.

Scarifying.—Shall include the loosening or stirring up of the surface or the breaking of a bond of the road. This is almost synonymous with loosening.

Screening.—Shall include the removal of all undesirable particles from any material by passing it through or over a screen, or both.

Shaping.—Shall include all processes of bringing road parts as subgrade, shoulders and courses to a regular form of section.

Spreading.—Shall include the scattering or distributing of any materials over a large surface in order to form a coating or layer of uniform depth.

Sprinkling.—Shall include the distribution of water, in a fine coat over a surface.

Stripping.—Shall include all removing or taking off the cover or burden from gravel pits or quarries.

Trimming.—Shall include the cutting off of small quantities of excavation to make the roadway or roadside conform to a regular outline or section.

Washing.—Shall include the removal of any undesirable matter from a material by use of water.

Washing and screening.—Shall include, in addition to washing, the processes explained under screening.

Wasting material.—Shall include all depositing on a dump or spoil bank of excavated materials that can not be used in embankment.

Waterproofing.—Shall include all protecting from water of concrete walls, etc., by the use of bituminous or any other material.

Working on joints.—Shall include all the labor made necessary by the introduction of expansion or contraction joints, natural or artificial, and also the openings between regular sets, as the joints in a brick roadway.

Wrecking.—Shall include the tearing down or destroying of any structures.

APPENDIX.

TABLES USEFUL IN DETERMINING COSTS AND PREPARING ESTIMATES.

TABLE 1.—*Some of the more common units of measurement used in collecting cost data on highway work.*

Aggregates, stone, sand, gravel, etc.	Cubic yard or ton of 2,000 pounds.
Bituminous materials	Gallon, or ton of 2,000 pounds.
Blocks: Brick, stone, asphalt, wood, etc.	Thousand.
Bridges and culverts:	
Metal	Pound, or ton of 2,000 pounds.
Painting, cleaning, erecting, or razing, often by	Linear foot.
Concrete, masonry, etc.	Cubic yard.
Cement, Portland, barrel of 4 bags	Bag, 94 pounds.
Clearing, clearing and grubbing, grubbing	Acre.
Concrete	Cubic foot or cubic yard.
Curbs, curb and gutter, gutters	Linear foot.
Culvert pipe—Metal, vitrified, concrete, wood, etc.	Linear foot.
Ditches, drains, drain tile	Linear foot.
Excavation, embankment, and earthwork in general	Cubic yard.
Fences, guard rails, etc.	Linear foot.
Lumber	Thousand board feet.
Pipe—Drain, sewer, pipe railing, etc.	Linear foot.
Piling	Linear foot.
Roadway: Courses, surfaces, subgrade, etc; construction, reconstruction, and maintenance operations	Usually square yard.
Steel and iron—Shapes, rods, pipes, mesh, etc.	Pound, or ton of 2,000 pounds.
Unit materials, structures, or parts, as blocks, inlet covers, monuments, sign posts, etc.	Single unit or thousand.

TABLE 2.—*Cubic yards of macadam compacted in place per 100 feet of road for various widths.*[1]

Width.	Depth.							
	2 inches.	2½ inches.	3 inches.	3½ inches.	4 inches.	5 inches.	6 inches.	7 inches.
Feet.	*Cu. yds.*	*Cu. yds.*	*Cu. yds.*	*Cu. yds.*	*Cu. yds.*	*Cu. yds.*	*Cu. yds.*	*Cu. yds.*
10	6.17	7.71	9.26	10.80	12.34	15.43	18.52	21.61
12	7.41	9.26	11.11	12.96	14.82	18.52	22.22	25.93
14	8.64	10.80	12.96	15.12	17.28	21.61	25.92	30.25
15	9.26	11.58	13.89	16.20	18.52	23.16	27.78	32.41
16	9.88	12.35	14.81	17.28	19.76	24.70	29.63	34.57
18	11.11	13.90	16.67	19.44	22.22	27.79	33.34	38.89
20	12.35	15.44	18.52	21.60	24.70	30.87	37.04	48.21
22	13.58	16.98	20.37	23.76	27.16	33.96	40.74	47.53

[1] Harger and Bonney.

TABLE 3.—*Gallons of bituminous material needed per 100 feet of varying width.*[1]

Width.	Gallons per square yard.				
	0.5	1.0	1.5	2.0	2.5
Feet.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
8	44.44	88.89	133.33	177.78	222.22
10	55.56	111.11	166.67	222.22	277.78
12	66.67	133.33	200.00	266.67	333.33
14	77.78	155.56	233.33	311.11	388.89
15	83.33	166.67	250.00	333.33	416.67
16	88.89	177.78	266.67	355.56	444.44
18	100.00	200.00	300.00	400.00	500.00
20	111.11	222.22	333.33	444.44	555.56
22	122.22	244.44	366.67	488.89	611.11
30	166.67	333.33	500.00	666.66	833.33
40	222.22	444.44	666.67	888.88	1,111.10

[1] Adapted from Harger and Bonney.

NOTE.—Bituminous road materials usually average from 45 to 50 gallons to the barrel.

TABLE 4.—*Feet in decimals of a mile.*[1]

Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.
1	0.00019	40	0.00758	600	0.11364	8,000	1.51515
2	.00038	50	.00947	700	.13258	9,000	1.70455
3	.00057	60	.01136	800	.15152	10,000	1.8939
4	.00076	70	.01326	900	.17046	20,000	3.7879
5	.00095	80	.01515	1,000	.18939	30,000	5.6818
6	.00114	90	.01705	2,000	.37879	40,000	7.5758
7	.00132	100	.01894	3,000	.56818	50,000	9.4697
8	.00152	200	.03788	4,000	.75758	60,000	11.3636
9	.00171	300	.05682	5,000	.94697	70,000	13.2576
10	.00189	400	.07576	6,000	1.13636	80,000	15.1515
20	.00379	500	.09470	7,000	1.32576	90,000	17.0455
30	.00568						

[1] Harger and Bonney.

TABLE 5.—*Number of square yards and acres per 100 feet and per mile for various widths.*

Width.	Square yards.		Acres.		Width.	Square yards.		Acres.	
	Per 100 feet.	Per mile.	Per 100 feet.	per mile.		Per 100 feet.	Per mile.	Per 100 feet.	Per mile.
Feet.					*Feet.*				
1	11.111	586.667	0.00230	0.121	26	288.889	15,253.3	0.05969	3.152
2	22.222	1,173.334	.00459	.242	28	311.111	16,426.7	.06428	3.394
3	33.333	1,760.001	.00689	.364	30	333.333	17,600.0	.06887	3.636
4	44.444	2,346.668	.00918	.485	32	355.556	18,773.3	.07346	3.879
5	55.556	2,933.335	.01148	.606	34	377.778	19,946.7	.07805	4.121
6	66.667	3,520.002	.01377	.727	36	400.000	21,120.0	.08265	4.364
7	77.778	4,106.669	.01607	.848	38	422.222	22,293.3	.08724	4.606
8	88.889	4,693.3	.01837	.970	40	444.444	23,466.7	.09183	4.848
9	100.000	5,280.0	.02066	1.091	42	466.667	24,640.0	.09642	5.090
10	111.111	5,866.6	.02296	1.212	44	488.889	25,813.3	.10101	5.333
12	133.333	7,040.0	.02755	1.454	46	511.111	26,986.7	.10560	5.575
14	155.556	8,213.3	.03214	1.697	48	533.333	28,160.0	.11019	5.818
15	166.667	8,800.0	.03444	1.818	50	555.556	29,333.4	.11478	6.061
16	177.778	9,386.7	.03673	1.939	60	666.667	35,200.0	.13774	7.273
18	200.000	10,560.0	.04132	2.182	70	777.778	41,066.7	.16070	8.485
20	222.222	11,734.0	.04591	2.424	80	888.889	46,933.3	.18366	9.697
22	244.444	12,906.7	.05051	2.666	90	1,000.000	52,800.0	.20661	10.909
24	266.667	14,080.0	.05510	2.909	100	1,111.111	58,666.7	.22957	12.121

TABLE 6.—*Cubical contents of various vehicles commonly used for transporting materials.*

[Loose measure.]

	Cubic feet.
Cart:	
One horse (regular size) 3 by 4 feet by 9 inches	9
One horse (large) 3 by 5½ feet by 12 inches	16.5
Concrete, push	5
Fresno scraper	9–14
Scraper drag:	
No. 1	7
No. 2	4–5
Scraper wheel:	
No. 1	9–10
No. 2	12–13
No. 2½	14
No. 3	16–17
Wagon:	
Slat-bottom dump, 3 by 9 feet by 12 inches	27
Dump bottom, 3 by 9 feet by 24 inches	54
Wheel-barrows:	
Regular size	2
Large	3

TABLE 7.—*Quantities required for 1 cubic yard of concrete for various mixtures.*

[Based on one barrel of cement being equal to 376 pounds, or 4 bags of 94 pounds each, and a barrel equal to 3.8 cubic feet and using stone, 45 per cent voids.]

Mixture.			Material necessary for 1 cubic yard of concrete.					
			Cement.		Sand.		Stone.	
Cement, C.	Sand, S.	Stone, G.	Barrels.	Bags.	Cubic yards.	Cubic feet.	Cubic yards.	Cubic feet.
1	2	4	1.57	6¼	0.44	11⅞	0.88	23¾
1	2½	5	1.30	5⅛	.46	12⅜	.92	24⅝
1	3	6	1.11	4½	.47	12¾	.94	25

A very handy formula for finding the amount of material to make 1 cubic yard of concrete is:

$$\text{The barrels of cement in 1 cubic yard} = \frac{11}{C+S+G}$$

Example:

$$\text{Barrels of cement to make a cubic yard of } 1:2\tfrac{1}{2}:5 \text{ mixture} = \frac{11}{1+2\frac{1}{2}+5} = 1.3 \text{ barrels.}$$

To find the cubic yards of sand: Multiply barrels of cement by proportional part of sand and the product by 0.141. Example: $1.3\times2\frac{1}{2}\times0.141=0.458$ cubic yards of sand. To find the cubic yards of stone, multiply the barrels of cement by the proportional part of stone and the product by 0.141. Example: $1.3\times5\times0.141=0.916$.

TABLE 8.—*Cubic yards for sum of end areas.*

[Length of prism 100 feet.]

Sum of end areas.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	.....	0.2	0.4	0.6	0.7	0.9	1.1	1.3	1.5	1.7
1	1.9	2.0	2.2	2.4	2.6	2.8	3.0	3.1	3.3	3.5
2	3.7	3.9	4.1	4.3	4.4	4.6	4.8	5.0	5.2	5.4
3	5.6	5.7	5.9	6.1	6.3	6.5	6.7	6.9	7.0	7.2
4	7.4	7.6	7.8	8.0	8.1	8.3	8.5	8.7	8.9	9.1
5	9.3	9.4	9.6	9.8	10.0	10.2	10.4	10.6	10.7	10.9
6	11.1	11.3	11.5	11.7	11.9	12.0	12.2	12.4	12.6	12.8
7	13.0	13.1	13.3	13.5	13.7	13.9	14.1	14.3	14.4	14.6
8	14.8	15.0	15.2	15.4	15.6	15.7	15.9	16.1	16.3	16.5
9	16.7	16.9	17.0	17.2	17.4	17.6	17.8	18.0	18.1	18.3
10	18.5	18.7	18.9	19.1	19.3	19.4	19.6	19.8	20.0	20.2
11	20.4	20.6	20.7	20.9	21.1	21.3	21.5	21.7	21.9	22.0
12	22.2	22.4	22.6	22.8	23.0	23.1	23.3	23.5	23.7	23.9
13	24.1	24.3	24.4	24.6	24.8	25.0	25.2	25.4	25.6	25.7
14	25.9	26.1	26.3	26.5	26.7	26.8	27.0	27.2	27.4	27.6
15	27.8	28.0	28.1	28.3	28.5	28.7	28.9	29.1	29.3	29.4
16	29.6	29.8	30.0	30.2	30.4	30.6	30.7	30.9	31.1	31.3
17	31.5	31.7	31.9	32.0	32.2	32.4	32.6	32.8	33.0	33.1
18	33.3	33.5	33.7	33.9	34.1	34.3	34.4	34.6	34.8	35.0
19	35.2	35.4	35.6	35.7	35.9	36.1	36.3	36.5	36.7	36.9
20	37.0	37.2	37.4	37.6	37.8	38.0	38.1	38.3	38.5	38.7
21	38.9	39.1	39.3	39.4	39.6	39.8	40.0	40.2	40.4	40.6
22	40.7	40.9	41.1	41.3	41.5	41.7	41.9	42.0	42.2	42.4
23	42.6	42.8	43.0	43.1	43.3	43.5	43.7	43.9	44.1	44.3
24	44.4	44.6	44.8	45.0	45.2	45.4	45.6	45.7	45.9	46.1
25	46.3	46.5	46.7	46.9	47.0	47.2	47.4	47.6	47.8	48.0
26	48.1	48.3	48.5	48.7	48.9	49.1	49.3	49.4	49.6	49.8
27	50.0	50.2	50.4	50.6	50.7	50.9	51.1	51.3	51.5	51.7
28	51.9	52.0	52.2	52.4	52.6	52.8	53.0	53.1	53.3	53.5
29	53.7	53.9	54.1	54.3	54.4	54.6	54.8	55.0	55.2	55.4
30	55.6	55.7	55.9	56.1	56.3	56.5	56.7	56.9	57.0	57.2
31	57.4	57.6	57.8	58.0	58.1	58.3	58.5	58.7	58.9	59.1
32	59.3	59.4	59.6	59.8	60.0	60.2	60.4	60.6	60.7	60.9
33	61.1	61.3	61.5	61.7	61.9	62.0	62.2	62.4	62.6	62.8
34	63.0	63.1	63.3	63.5	63.7	63.9	64.1	64.3	64.4	64.6
35	64.8	65.0	65.2	65.4	65.6	65.7	65.9	66.1	66.3	66.5
36	66.7	66.9	67.0	67.2	67.4	67.6	67.8	68.0	68.1	68.3
37	68.5	68.7	68.9	69.1	69.3	69.4	69.6	69.8	70.0	70.2
38	70.4	70.6	70.7	70.9	71.1	71.3	71.5	71.7	71.9	72.0
39	72.2	72.4	72.6	72.8	73.0	73.1	73.3	73.5	73.7	73.9
40	74.1	74.3	74.4	74.6	74.8	75.0	75.2	75.4	75.6	75.7
41	75.9	76.1	76.3	76.5	76.7	76.9	77.0	77.2	77.4	77.6
42	77.8	78.0	78.1	78.3	78.5	78.7	78.9	79.1	79.3	79.4
43	79.6	79.8	80.0	80.2	80.4	80.6	80.7	80.9	81.1	81.3
44	81.5	81.7	81.9	82.0	82.2	82.4	82.6	82.8	83.0	83.1
45	83.3	83.5	83.7	83.9	84.1	84.3	84.4	84.6	84.8	85.0
46	85.2	85.4	85.6	85.7	85.9	86.1	86.3	86.5	86.7	86.9
47	87.0	87.2	87.4	87.6	87.8	88.0	88.1	88.3	88.5	88.7
48	88.9	89.1	89.3	89.4	89.6	89.8	90.0	90.2	90.4	90.6
49	90.7	90.9	91.1	91.3	91.5	91.7	91.9	92.0	92.2	92.4
50	92.6	92.8	93.0	93.1	93.3	93.5	93.7	93.9	94.1	94.3
51	94.4	94.6	94.8	95.0	95.2	95.4	95.6	95.7	95.9	96.1
52	96.3	96.5	96.7	96.9	97.0	97.2	97.4	97.6	97.8	98.0
53	98.1	98.3	98.5	98.7	98.9	99.1	99.3	99.4	99.6	99.8
54	100.0	100.2	100.4	100.6	100.7	100.9	101.1	101.3	101.5	101.7
55	101.9	102.0	102.2	102.4	102.6	102.8	103.0	103.1	103.3	103.5
56	103.7	103.9	104.1	104.3	104.4	104.6	104.8	105.0	105.2	105.4
57	105.6	105.7	105.9	106.1	106.3	106.5	106.7	106.9	107.0	107.2
58	107.4	107.6	107.8	108.0	108.1	108.3	108.5	108.7	108.9	109.1
59	109.3	109.4	109.6	109.8	110.0	110.2	110.4	110.6	110.7	110.9
60	111.1	111.3	111.5	111.7	111.9	112.0	112.2	112.4	112.6	112.8
61	113.0	113.1	113.3	113.5	113.7	113.9	114.1	114.3	114.4	114.6
62	114.8	115.0	115.2	115.4	115.6	115.7	115.9	116.1	116.3	116.5
63	116.7	116.9	117.0	117.2	117.4	117.6	117.8	118.0	118.1	118.3
64	118.5	118.7	118.9	119.1	119.3	119.4	119.6	119.8	120.0	120.2
65	120.4	120.6	120.7	120.9	121.1	121.3	121.5	121.7	121.9	122.0
66	122.2	122.4	122.6	122.8	123.0	123.1	123.3	123.5	123.7	123.9
67	124.1	124.3	124.4	124.6	124.8	125.0	125.2	125.4	125.6	125.7
68	125.9	126.1	126.3	126.5	126.7	126.9	127.0	127.2	127.4	127.6
69	127.8	128.0	128.1	128.3	128.5	128.7	128.9	129.1	129.3	129.4
70	129.6	129.8	130.0	130.2	130.4	130.6	130.7	130.9	131.1	113.3
71	131.5	131.7	131.9	132.0	132.2	132.4	132.6	132.8	133.0	133.1
72	133.3	133.5	133.7	133.9	134.1	134.2	134.4	134.6	134.8	135.0
73	135.2	135.4	135.6	135.7	135.9	136.1	136.3	136.5	136.7	136.9
74	137.0	137.2	137.4	137.6	137.8	138.0	138.1	138.3	138.5	138.7
75	138.9	139.1	139.3	139.4	139.6	139.8	140.0	140.2	140.4	140.6
76	140.7	140.9	141.1	141.3	141.5	141.7	141.9	142.0	142.2	142.4

TABLE 8.—*Cubic yards for sum of end areas*—Continued.

[Length of prism 100 feet.]

Sum of end areas.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
77	142.6	142.8	143.0	143.1	143.3	143.5	143.7	143.9	144.1	144.3
78	144.4	144.6	144.8	145.0	145.2	145.4	145.6	145.7	145.9	146.1
79	146.3	146.5	146.7	146.9	147.0	147.2	147.4	147.6	147.8	148.0
80	148.1	148.3	148.5	148.7	148.9	149.1	149.3	149.4	149.6	149.8
81	150.0	150.2	150.4	150.6	150.7	150.9	151.1	151.3	151.5	151.7
82	151.9	152.0	152.2	152.4	152.6	152.8	153.0	153.1	153.3	153.5
83	153.7	153.9	154.1	154.3	154.4	154.6	154.8	155.0	155.2	155.4
84	155.6	155.7	155.9	156.1	156.3	156.5	156.7	156.9	157.0	157.2
85	157.4	157.6	157.8	158.0	158.1	158.3	158.5	158.7	158.9	159.1
86	159.3	159.4	159.6	159.8	160.0	160.2	160.4	160.6	160.8	160.9
87	161.1	161.3	161.5	161.7	161.9	162.0	162.2	162.4	162.6	162.8
88	163.0	163.1	163.3	163.5	163.7	163.9	164.1	164.3	164.4	164.6
89	164.8	165.0	165.2	165.4	165.6	165.7	165.9	166.1	166.3	166.5
90	166.7	166.9	167.0	167 2	167.4	167.6	167.8	168.0	168.1	168.3
91	168.5	168.7	168.9	169.1	169.3	169.4	169.6	169.8	170.0	170.2
92	170.4	170.6	170.7	170.9	171.1	171.3	171.5	171.7	171.9	172.0
93	172.2	172.4	172.6	172.8	173.0	173.1	173.3	173.5	173.7	173.9
94	174.1	174.3	174.4	174.6	174.8	175.0	175.2	175.4	175.6	175.7
95	175.9	176.1	176.3	176.5	176.7	176.9	177.0	177.2	177.4	177.6
96	177.8	178.0	178.1	178.3	178.5	178.7	178.9	179.1	179.3	179.4
97	179.6	179.8	180.0	180.2	180.4	180.6	180.7	180.9	181.1	181.3
98	181.5	181.7	181.9	182.0	182.2	182.4	182.6	182.8	183.0	183.1
99	183.3	183.5	183.7	183.9	184.1	184.3	184.4	184.6	184.8	185.0
100	185.2	185.4	185.6	185.7	185.9	186.1	186.3	186.5	186.7	186.9
200	370.4	.....	700.0	1,296.3	.....	3,000.0	5,555.6	.....	8,000.0	14,814.8
300	555.6	.....	800.0	1,481.5	.....	4,000.0	7,407.4	.....	9,000.0	16,666.7
400	740.7	.....	900.0	1,666.7	.....	5,000.0	9,259.3	.....	10,000.0	18,518.5
500	925.9	.....	1,000.0	1,851.9	.....	6,000.0	11,111.1	.....	.....	.....
600	1,111.1	.....	2,000.0	3,703.7	.....	7,000.0	12,963.3	.....	.....	.....

NOTE.—By Wisconsin State Highway Commission.

TABLE 9.[1]—*Board measure.*

[Board feet per foot of length for various widths and thicknesses.]

Width in inches.	Thickness in inches.																		
0	1	1½	2	2½	3	3½	4	4½	5	5½	6	7	8	9	10	11	12	14	16
1	0.0833	0.1250	0.1667	0.2083	0.2500	0.2917	0.3333	0.3750	0.4167	0.4583	0.5000	0.5833	0.6667	0.7500	0.8333	0.9167	1.000	1.167	1.333
1½	.1250	.1875	.2500	.3125	.3750	.4063	.5000	.5625	.6250	.6875	.7500	.8750	1.0000	1.1250	1.2500	1.3750	1.500	1.750	2.000
2	.1667	.2500	.3333	.4688	.5625	.5833	.6667	.7500	.8333	.9167	1.0000	1.1670	1.3330	1.5000	1.6670	1.8330	2.000	2.333	2.667
2½	.2083	.3125	.4167	.5208	.6250	.7292	.8333	.9375	1.0420	1.1460	1.2500	1.4580	1.6670	1.8750	2.0830	2.2920	2.500	2.917	3.333
3	.2500	.3750	.5000	.6250	.7500	.8750	1.0000	1.1250	1.2500	1.3750	1.5000	1.7500	2.0000	2.2500	2.5000	2.7500	3.000	3.500	4.000
3½	.2917	.4375	.5833	.7292	.8750	1.0210	1.1670	1.3130	1.4580	1.6040	1.7500	2.0420	2.3330	2.6250	2.9170	3.2080	3.500	4.083	4.667
4	.3333	.5000	.6667	.8333	1.0000	1.1670	1.3330	1.5000	1.6670	1.8330	2.0000	2.3330	2.6670	3.0000	3.3330	3.6670	4.000	4.667	5.333
4½	.3750	.5625	.7500	.9375	1.1250	1.3130	1.5000	1.6880	1.8750	2.0630	2.2500	2.6250	3.0000	3.3750	3.7500	4.1250	4.500	5.250	6.000
5	.4167	.6250	.8333	1.0420	1.2500	1.4570	1.6660	1.8750	2.0830	2.2920	2.5000	2.9170	3.3330	3.7500	4.1670	4.5830	5.000	5.833	6.667
5½	.4583	.6875	.9167	1.1460	1.3750	1.6030	1.8330	2.0630	2.2920	2.5210	2.7500	3.2080	3.6670	4.1250	4.5830	5.0420	5.500	6.417	7.333
6	.5000	.7500	1.0000	1.2500	1.5000	1.7500	2.0000	2.2500	2.5000	2.7500	3.0000	3.5000	4.0000	4.5000	5.0000	5.5000	6.000	7.000	8.000
7	.5833	.8750	1.1670	1.4580	1.7500	2.0420	2.3330	2.6250	2.9170	3.2080	3.5000	4.0830	4.6670	5.2500	5.8330	6.4170	7.000	8.167	9.333
8	.6667	1.0000	1.3330	1.6670	2.0000	2.3330	2.6670	3.0000	3.3330	3.6670	4.0000	4.6670	5.3330	6.0000	6.6670	7.3330	8.000	9.333	10.670
9	.7500	1.1250	1.5000	1.8750	2.2500	2.6250	3.0000	3.3750	3.7500	4.1250	4.5000	5.2490	6.0000	6.7500	7.5000	8.2500	9.000	10.500	12.000
10	.8333	1.2500	1.6670	2.0830	2.5000	2.9170	3.3330	3.7500	4.1670	4.5830	5.0000	5.8330	6.6670	7.5000	8.3330	9.1670	10.000	11.670	13.330
11	.9167	1.3750	1.8330	2.2920	2.7500	3.2080	3.6660	4.1250	4.5830	5.0420	5.5000	6.4170	7.3330	8.2500	9.1670	10.0800	11.000	12.830	14.670
12	1.0000	1.5000	2.0000	2.5000	3.0000	3.5000	4.0000	4.5000	5.0000	5.5000	6.0000	7.0000	8.0000	9.0000	10.0000	11.0000	12.000	14.000	16.000
13	1.0830	1.6250	2.1670	2.7080	3.2500	3.7920	4.3330	4.8750	5.4170	5.9580	6.5000	7.5830	8.6660	9.7500	10.8300	11.9200	13.000	15.170	17.330
14	1.1670	1.7500	2.3330	2.9170	3.5000	4.0830	4.6670	5.2500	5.8330	6.4170	7.0000	8.1670	9.3330	10.5000	11.6700	12.8300	14.000	16.330	18.670
15	1.2500	1.8750	2.5000	3.1250	3.7500	4.3750	5.0000	5.6250	6.2500	6.8750	7.5000	8.7500	10.0000	11.2500	12.5000	13.7500	15.000	17.500	20.000
16	1.3330	2.0000	2.6670	3.3330	4.0000	4.6670	5.3330	6.0000	6.6670	7.3330	8.0000	9.3330	10.6700	12.0000	13.3300	14.6700	16.000	18.670	21.330
18	1.5000	2.2500	3.0000	3.7500	4.5000	5.2500	6.0000	6.7500	7.5000	8.2500	9.0000	10.5000	12.0000	13.5000	15.0000	16.5000	18.000	21.000	24.000
20	1.6670	2.5000	3.3330	4.1670	5.0000	5.8330	6.6670	7.5000	8.3330	9.1670	10.0000	11.6700	13.3300	15.0000	16.6700	18.3300	20.000	23.330	26.670

[1] From Byrnes Inspection Pocket Book.

TABLE 10.—

Rate.	Hours.										
	¼	½	¾	1	2	3	4	5	6	7	8
$0.100	$0.02	$0.05	$0.07	$0.10	$0.20	$0.30	$0.40	$0.50	$0.60	$0.70	$0.80
.105	.02	.05	.07	.10	.21	.31	.42	.52	.63	.73	.84
.110	.02	.05	.08	.11	.22	.33	.44	.55	.66	.77	.88
.115	.03	.06	.08	.11	.23	.34	.46	.57	.69	.80	.92
.120	.03	.06	.09	.12	.24	.36	.48	.60	.72	.84	.96
.125	.03	.06	.09	.12	.25	.37	.50	.62	.75	.87	1.00
.130	.03	.06	.09	.13	.26	.39	.52	.65	.78	.91	1.04
.135	.03	.07	.10	.13	.27	.40	.54	.67	.81	.94	1.08
.140	.03	.07	.10	.14	.28	.42	.56	.70	.84	.98	1.12
.145	.03	.07	.10	.14	.29	.43	.58	.72	.87	1.01	1.16
.150	.03	.07	.11	.15	.30	.45	.60	.75	.90	1.05	1.20
.155	.04	.08	.12	.15	.31	.46	.62	.77	.93	1.08	1.24
.160	.04	.08	.12	.16	.32	.48	.64	.80	.96	1.12	1.28
.165	.04	.08	.12	.16	.33	.49	.66	.82	.99	1.15	1.32
.170	.04	.08	.12	.17	.34	.51	.68	.85	1.02	1.19	1.36
.175	.04	.09	.13	.17	.35	.52	.70	.87	1.05	1.22	1.40
.180	.04	.09	.13	.18	.36	.54	.72	.90	1.08	1.26	1.44
.185	.04	.09	.13	.18	.37	.55	.74	.92	1.11	1.29	1.48
.190	.04	.09	.14	.19	.38	.57	.76	.95	1.14	1.33	1.52
.195	.05	.10	.14	.19	.39	.58	.78	.97	1.17	1.36	1.56
.200	.05	.10	.15	.20	.40	.60	.80	1.00	1.20	1.40	1.60
.225	.06	.11	.17	.22	.45	.67	.90	1.12	1.35	1.57	1.80
.250	.06	.12	.19	.25	.50	.75	1.00	1.25	1.50	1.75	2.00
.275	.07	.14	.21	.27	.55	.82	1.10	1.37	1.65	1.92	2.20
.300	.07	.15	.22	.30	.60	.90	1.20	1.50	1.80	2.10	2.40
.325	.08	.16	.24	.32	.65	.97	1.30	1.62	1.95	2.27	2.60
.350	.08	.17	.26	.35	.70	1.05	1.40	1.75	2.10	2.45	2.80
.375	.09	.19	.28	.37	.75	1.12	1.50	1.87	2.25	2.62	3.00
.400	.10	.20	.30	.40	.80	1.20	1.60	2.00	2.40	2.80	3.20
.425	.10	.21	.31	.42	.85	1.27	1.70	2.12	2.55	2.97	3.40
.450	.11	.22	.34	.45	.90	1.35	1.80	2.25	2.70	3.15	3.60
.475	.12	.24	.36	.47	.95	1.42	1.90	2.37	2.85	3.32	3.80
.500	.12	.25	.37	.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00
.525	.13	.26	.39	.52	1.05	1.57	2.10	2.62	3.15	3.67	4.20
.550	.14	.27	.41	.55	1.10	1.65	2.20	2.75	3.30	3.85	4.40
.575	.14	.28	.43	.57	1.15	1.72	2.30	2.87	3.45	4.02	4.60
.600	.15	.30	.45	.60	1.20	1.80	2.40	3.00	3.60	4.20	4.80
.625	.15	.31	.47	.62	1.25	1.87	2.50	3.12	3.75	4.38	5.00
.650	.16	.32	.49	.65	1.30	1.95	2.60	3.25	3.90	4.55	5.20
.675	.17	.34	.50	.67	1.35	2.02	2.70	3.37	4.05	4.72	5.40
.700	.17	.35	.52	.70	1.40	2.10	2.80	3.50	4.20	4.90	5.60
.725	.18	.36	.54	.72	1.45	2.17	2.90	3.62	4.35	5.07	5.80
.750	.19	.37	.56	.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00
.775	.19	.39	.58	.77	1.55	2.32	3.10	3.87	4.65	5.42	6.20
.800	.20	.40	.60	.80	1.60	2.40	3.20	4.00	4.80	5.60	6.40
.825	.21	.41	.62	.82	1.65	2.47	3.30	4.12	4.95	5.77	6.60
.850	.21	.42	.64	.85	1.70	2.55	3.40	4.25	5.10	5.95	6.80
.875	.22	.44	.66	.87	1.75	2.62	3.50	4.37	5.25	6.12	7.00
.900	.22	.45	.67	.90	1.80	2.70	3.60	4.50	5.40	6.30	7.20
.925	.23	.46	.69	.92	1.85	2.77	3.70	4.62	5.55	6.47	7.40
.950	.24	.47	.71	.95	1.90	2.85	3.80	4.75	5.70	6.65	7.60
.975	.24	.49	.73	.97	1.95	2.92	3.90	4.87	5.85	6.82	7.80
1.000	.25	.50	.75	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00

Wage table.

Hours—Continued.											Rate.
9	10	20	30	40	50	60	70	80	90	100	
$0.90	$1.00	$2.00	$3.00	$4.00	$5.00	$6.00	$7.00	$8.00	$9.00	$10.00	$0.100
.94	1.05	2.10	3.15	4.20	5.25	6.30	7.35	8.40	9.45	10.50	.105
.99	1.10	2.20	3.30	4.40	5.50	6.60	7.70	8.80	9.90	11.00	.110
1.03	1.15	2.30	3.45	4.60	5.75	6.90	8.05	9.20	10.35	11.50	.115
1.08	1.20	2.40	3.60	4.80	6.00	7.20	8.40	9.60	10.80	12.00	.120
1.12	1.25	2.50	3.75	5.00	6.25	7.50	8.75	10.00	11.25	12.50	.125
1.17	1.30	2.60	3.90	5.20	6.50	7.80	9.10	10.40	11.70	13.00	.130
1.21	1.35	2.70	4.05	5.40	6.75	8.10	9.45	10.80	12.15	13.50	.135
1.26	1.40	2.80	4.20	5.60	7.00	8.40	9.80	11.20	12.60	14.00	.140
1.30	1.45	2.90	4.35	5.80	7.25	8.70	10.15	11.60	13.05	14.50	.145
1.35	1.50	3.00	4.50	6.00	7.50	9.00	10.50	12.00	13.50	15.00	.150
1.39	1.55	3.10	4.65	6.20	7.75	9.30	10.85	12.40	13.95	15.50	.155
1.44	1.60	3.20	4.80	6.40	8.00	9.60	11.20	12.80	14.40	16.00	.160
1.48	1.65	3.30	4.95	6.60	8.25	9.90	11.55	13.20	14.85	16.50	.165
1.53	1.70	3.40	5.10	6.80	8.50	10.20	11.90	13.60	15.30	17.00	.170
1.57	1.75	3.50	5.25	7.00	8.75	10.50	12.25	14.00	15.75	17.50	.175
1.62	1.80	3.60	5.40	7.20	9.00	10.80	12.60	14.40	16.20	18.00	.180
1.66	1.85	3.70	5.55	7.40	9.25	11.10	12.95	14.80	16.65	18.50	.185
1.71	1.90	3.80	5.70	7.60	9.50	11.40	13.30	15.20	17.10	19.00	.190
1.75	1.95	3.90	5.85	7.80	9.75	11.70	13.65	15.60	17.55	19.50	.195
1.80	2.00	4.00	6.00	8.00	10.00	12.00	14.00	16.00	18.00	20.00	.200
2.02	2.25	4.50	6.75	9.00	11.25	13.50	15.75	18.00	20.25	22.50	.225
2.25	2.50	5.00	7.50	10.00	12.50	15.00	17.50	20.00	22.50	25.00	.250
2.47	2.75	5.50	8.25	11.00	13.75	16.50	19.25	22.00	24.75	27.50	.275
2.70	3.00	6.00	9.00	12.00	15.00	18.00	21.00	24.00	27.00	30.00	.300
2.92	3.25	6.50	9.75	13.00	16.25	19.50	22.25	26.00	29.25	32.50	.325
3.15	3.50	7.00	10.50	14.00	17.50	21.00	24.50	28.00	31.50	35.00	.350
3.37	3.75	7.50	11.25	15.00	18.75	22.50	26.25	30.00	33.25	37.50	.375
3.60	4.00	8.00	12.00	16.00	20.00	24.00	28.00	32.00	36.00	40.00	.400
3.82	4.25	8.50	12.75	17.00	21.25	25.50	29.75	34.00	38.25	42.50	.425
4.05	4.50	9.00	13.50	18.00	22.50	27.00	31.50	36.00	40.50	45.00	.450
4.27	4.75	9.50	14.25	19.00	23.75	28.50	33.25	38.00	42.25	47.50	.475
4.50	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00	.500
4.72	5.25	10.50	15.75	21.00	26.25	31.50	36.25	42.00	47.25	52.50	.525
4.95	5.50	11.00	16.50	22.00	27.50	33.00	38.50	44.00	49.50	55.00	.550
5.17	5.75	11.50	17.25	23.00	28.75	34.50	40.25	46.00	51.75	57.50	.575
5.40	6.00	12.00	18.00	24.00	30.00	36.00	42.00	48.00	54.00	60.00	.600
5.62	6.25	12.50	18.75	25.00	31.25	37.50	43.75	50.00	56.25	62.50	.625
5.85	6.50	13.00	19.50	26.00	32.50	39.00	45.50	52.00	58.50	65.00	.650
6.07	6.75	13.50	20.25	27.00	33.75	40.50	47.25	54.00	60.75	67.50	.675
6.30	7.00	14.00	21.00	28.00	35.00	42.00	49.00	56.00	63.00	70.00	.700
6.52	7.25	14.50	21.75	29.00	36.25	43.50	50.75	58.00	65.25	72.50	.725
6.75	7.50	15.00	22.50	30.00	37.50	45.00	52.50	60.00	67.50	75.00	.750
6.97	7.75	15.50	23.25	31.00	38.75	46.50	54.25	62.00	69.75	77.50	.775
7.20	8.00	16.00	24.00	32.00	40.00	48.00	56.00	64.00	72.00	80.00	.800
7.42	8.25	16.50	24.75	33.00	41.25	49.50	57.75	66.00	74.25	82.50	.825
7.65	8.50	17.00	25.50	34.00	42.50	51.00	59.50	68.00	76.50	85.00	.850
7.87	8.75	17.50	26.25	35.00	43.75	52.50	61.25	70.00	78.75	87.50	.875
8.10	9.00	18.00	27.00	36.00	45.00	54.00	63.00	72.00	81.00	90.00	.900
8.32	9.25	18.50	27.75	37.00	46.25	55.50	64.75	74.00	83.25	92.50	.925
8.55	9.50	19.00	28.50	38.00	47.50	57.00	66.50	76.00	85.50	95.00	.950
8.77	9.75	19.50	29.25	39.00	48.75	58.50	68.25	78.00	87.75	97.50	.975
9.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00	100.00	1.000

PLANT AND EQUIPMENT RENTAL TABLE.

The information contained in this table has been gathered from various sources and as complete data are given in connection therewith as were available at the time it was secured. While all of the rates given were those actually used on construction work, their use as a basis for rentals in specific cases is not recommended.

Schedule of rental rates used during the season 1917 on work of considerable magnitude.

[The rates mentioned are per day.]

Automobiles	$5.00
Adding and listing machines	.20
Buckets, tipple and bottom dump	.25
Boring machine, pneumatic	.50
Boring machine, electric	.50
Buckets, orange-peel, 1 yard	3.50
Buckets, orange-peel, less than 1 yard	2.00
Buckets, clamshell	2.00
Boiler, and 3-drum engine	3.50
Boiler, and 2-drum engine	3.00
Boiler, and 1-drum engine	2.50
Boiler only, 30 horsepower and smaller	1.50
Boiler only, larger than 30 horsepower	2.00
Block machine, concrete	1.50
Cars, skip, 1½ yards	.25
Cars, skip, 3 yards	.50
Cars, steel, 1 yard and smaller	.15
Cars, 4 yards, wooden	.25
Cars, 6 yards, wooden	.75
Cars, 12 yards, wooden	2.00
Cars, 1 hopper, radial gate	.25
Crushers only	2.00
Crushers, with elevator and screen	3.00
Conveyor, gravity, per 100 feet	1.00
Compressor, 10 by 10 with steam engine	2.50
Compressor, 8 by 8 belt driven	1.00
Compressor, with gasoline engine on wheels	5.00
Compressor, Westinghouse, 9½ inch	1.00
Cableways, without engine	4.00
Drill, auto traction	5.00
Dump wagons	.25
Diving outfit with pumps	10.00
Derricks, 60 feet to 85 feet	2.00
Derricks, 30 feet to 59 feet	1.50
Derricks, less than 30 feet	1.00
Derricks, breast	.25
Derricks, circle swing	.25
Elevators, platform or bucket	.25
Elevators, with bins for concrete	.50
Engines, skeleton, 3 drum	2.00
Engines, skeleton, 2 drum	1.50
Engines, skeleton, 1 drum	1.00
Engines, steam, horizontal, 11 to 40 horsepower	1.50

Engines, steam, upright, to 10 horsepower	$0.50
Engines, gasoline, to 8 horsepower	.50
Engines, 2-drum, with electric motor	4.00
Engines, gasoline, 10 horsepower	1.00
Engines, derrick, swinging	.50
Hammers, riveting	.25
Hod elevating machine	1.00
Leveling instruments, engineers'	.25
Locomotive, 36-inch gauge	5.00
Locomotive, standard gauge	10.00
Mixers, with boiler sideloader	4.00
Mixers, with electric motors, 1 yard	4.00
Mixers without boiler, less than 1 yard	2.00
Mixers without boiler, 1 yard and larger	3.50
Mixers with gasoline engine	3.00
Motorcycles	1.00
Motors, 2 horsepower	.15
Motors, 5 horsepower	.25
Motors, 10 horsepower	.50
Motors, 25 horsepower	1.00
Motors, 50 horsepower	2.00
Pumps, centrifugal, 10-inch, belt driven	3.00
Pumps, centrifugal, 10-inch, with motor attached	4.00
Pumps, centrifugal, 8-inch, steam connected	2.00
Pumps, centrifugal, 6-inch, steam connected	1.50
Pumps, centrifugal, 4-inch, steam connected	1.00
Pumps, duplex and triplex to 3-inch	.50
Pumps, pulsometor to 4-inch	1.55
Pumps, diaphragm	.20
Pumps, diaphragm, with gas engine	1.05
Pumps, triplex, with belt drive	.20
Pile drivers, drop	1.50
Pile drivers, drop, with single drum engine and boiler	3.50
Pile hammers, steam, up to 2,500 pounds	3.00
Pile hammers, steam, larger than 2,500 pounds	5.00
Rail, per ton	.06
Roller, horse	1.00
Steam drills	1.00
Small air drills	.50
Steam roller	8.00
Steam shovel	30.00
Sprinkling cart	1.00
Saw benches	.25
Saw benches, with motor or gasoline engine	.50
Scale boxes	.25
Scraper, wheel	.50
Transits	.50
Typewriter	.10

Fuel and lubricants were not included in these prices, nor was the cost of repairs, all of which were borne by the organization using the equipment. All equipment was to be returned to the owner in good condition.

Rental paid for use of equipment on State highway work during the year 1917, by contract.

Air compressor drill outfits while necessarily on site of work, per day	$3.00
Crusher, including screens and bins, per day	8.00
Concrete mixer and labor, per cubic yard of concrete	.60–1.72
Grader while necessarily on site of work, per day	15.00
Steam roller, per linear foot of roadway rolled	.06
Steam shovel while necessarily on site of work, per day	20.00

Small tools, such as lanterns, rubber boots, axes, hammers, drills, bars, plows, harrows, picks, shovels, wheelbarrows, and of like character, were included in the unit prices paid for completed work. The work was done by a contractor who was paid a fixed amount for units of work completed. All materials used were paid for by the State. The contractor furnished coal, oil, repairs, etc., for his equipment at the rentals quoted.

Rental paid for use of equipment on State highway work, season of 1917; work done by State forces, equipment owned by towns and individuals.

Boilers, about 25 horsepower, per day	$5.00
Crusher, screens, bins, and engine, per day	10.00
Heater (for stone) and engine, per day	5.00
Mixer and steam engine, per day	5.00
Water cart, per day	.50
Truck, 3-ton capacity, driver, fuel, repairs, and all supplies necessary, per day	18.00

Fuel, lubricant, and repairs furnished by State.

REFERENCES.

The authors acknowledge their indebtedness to the following sources of information:

The cost-account systems of the following State highway departments: Arizona, Illinois, Maryland, Oregon, Pennsylvania, and Wisconsin; "Efficient Cost Keeping," by E. St. Elmo Lewis; "Efficiency," by Harrington Emerson; "Cost Data," by H. P. Gillette; "Cost-Keeping and Scientific Management," by H. A. Evans; "Cost Records for Executives as a Means of Plant Control," by B. A. Franklin; "Cost Accounting and Management Engineering," by H. P. Gillette and R. P. Dana; "Cost Accounts," by L. W. Hawkins; "Psychology and Industrial Efficiency," by Hugo Munsterberg; "Cost Accounts," by J. L. Nicholson; "The Principles of Scientific Management," by Frederick W. Taylor; "Cost Accounting," by J. R. Wildman; "Modern Accounting," by H. R. Hatfield; "The Handbook of Municipal Accounting," by the Bureau of Municipal Research; The Cost-Accounting System of the Ontario Highway Department; the Cost-Accounting System used by the Bureau of Public Works of the Philippine Islands; an article on "Cost Accounting," by Capt. Godfrey, and the subsequent discussions on the subject in the Army Engineers' Magazine; "Memoirs of Army Engineers;" and in addition the Study of Cost-Accounting Systems in use in many counties, cities, and towns in the United States, and the chapter on "Cost Finding" in Volume XI of the Alexander Hamilton Institute, and the Transactions of the American Society of Civil Engineers.

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